Curricular Implementation Patterns and Their Potential Influence on Student Achievement

BY

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THESIS

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This thesis is dedicated to my mom, Halina Brodowinska, and my daughters, Izabella and Luna Bruscianelli.

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SUMMARY

In education reform, contemporary pedagogical practices that offer students the means to learn and develop 21st century skills are continuously being explored and vetted. Problem-based learning (PBL), an approach that emphasizes the role of authentic, ill-structured problems as impetus for collaborative learning and the development of problem-solving and critical thinking skills, has been considered a promising alternative to traditional methods. However, research examining the effectiveness of PBL has yielded inconsistent results. Fidelity of PBL implementation has been theorized to be one possible culprit in producing differential student outcomes. Therefore, the purpose of this investigation was to identify instructional profiles of PBL enactment and determine if differences in implementation might play a role in student learning.

For this study, 53 middle school teachers were systematically observed over the span of 12 weeks while enacting a PBL curriculum. Cluster analysis of classroom observation data revealed two predominant implementation profiles; one in which teachers exemplified PBL tutor characteristics and supported their students' learning throughout, and the other in which a hands-off approach to implementation was assumed by teachers and required students to work independently to a considerable degree. Analysis of covariance revealed a statistically significant difference between the two groups on student post-assessment scores. Students of teachers whose implementation closely aligned with PBL principles outperformed the students of teachers that took the hands-off approach ($F_{(1, 909)} = 32.849$, $p < .004$). Content analysis of teacher interviews in addition to teacher background information and demographic data revealed that teachers who did not deliver the PBL program as intended, appeared to face greater challenges.

They were predominantly new to the program and expressed that their students found the curriculum overwhelming.

The findings of this study indicate that differences in PBL implementation do exist and can impact student learning outcomes. Nevertheless, in order to identify the supports and training necessary for teachers to enact it with greater fidelity, it is critical to investigate PBL implementation more comprehensively to better understand its efficacy in different contexts and under varying circumstances.

Chapter 1: Introduction

The state of education has been undergoing a slow metamorphosis over the last several decades, driven by the nation's less than optimal performance on various assessments at the national and international level. The results of the 2015 National Assessment of Educational Progress (NAEP) indicated that approximately just one-third of eighth-graders in the U.S. were considered proficient in science and math. On an international level, the nation was ranked 24th in science and only 38th in math among 71 countries assessed (PISA, 2015). Given the nation's mediocre performance on these and other standardized international assessments, discipline specific learning standards, as well as numerous reform initiatives have arisen. The advances in research regarding how people learn and the necessity to advance learners' knowledge and skills to meet the demands of the 21st century have greatly impacted this evolution (Pellegrino & Hilton, 2012). The focus has shifted from traditional instructional practices and learning environments that emphasize memorization of facts and procedures, to practices identified to support students' construction of deep, contextual understanding and development of higher order thinking skills (i.e. inquiry, reasoning, and problem-solving). What has also become valued are skills that help students become scientifically literate citizens, such as the ability to self-direct their learning, make evidence-based decisions, and effectively collaborate with others (Hand et al., 2010). Although many reform-based instructional methods have been brought to the forefront, one with great potential for student learning and for meeting the current objectives is problem-based learning (PBL).

Problem-based learning is a constructivist approach to teaching and learning, which emphasizes the role of authentic, ill-structured problems in knowledge construction and promotes the development of problem-solving and critical thinking skills (Van Berkel & Dolmans, 2006). It is student-centered in nature, hence offering students an environment where they are able to take ownership of their learning and develop self-directed learning skills, consequently equipping them with tools to become life-long learners. In PBL, students work collaboratively with peers on solving complex problems that emulate professional practice, which readies them to apply their knowledge in a real world environment. Although the teacher's role in PBL shifts from being central to being more peripheral, the teacher's involvement in PBL is key to its facilitation and to the guiding of students' learning. The teacher or PBL tutor, models appropriate meta-cognitive behaviors and reasoning processes for the students to adopt. He/she continually assesses student comprehension and accordingly, coaches and scaffolds students' progress as they grapple with the problem at hand as well as the new information they gather. The teacher also plays a key role in promoting group functioning as a whole.

The design of problem-based learning stemmed from McMaster University Medical School in order to improve the ability of medical students to apply knowledge to clinical settings, which was inadequately supported by traditional instruction (Barrows, 1986). And although it emerged in the 1960's, its foundational principles could be traced back to the ideology promoted by educational philosopher, John Dewey, several decades earlier. Dewey's (1931) theories of learning emphasized the importance of students' active participation in the learning process and engagement in free inquiry. His statement that, "true learning is based on discovery guided by mentoring rather than the transmission of knowledge" (Kenny, 1998, p.15), points to the direct parallels that can be drawn between his beliefs and the design of PBL learning environments. Since the work of Dewey and others, such as Jean Piaget and Lev Vygotsky, influenced the constructivist view of learning, PBL can be further explained by the learning principles derived from this perspective (Fosnot & Perry, 2005). Hence, learning in PBL is considered to be an active process of reconstruction of one's mental models, initially spurred by the PBL problem and further stimulated by participation in collaborative deliberations of the PBL tutorial group regarding how to solve the presented dilemma (Duffy & Cunningham, 1996).

The potential of PBL as a vehicle for promoting the development of deep, flexible knowledge, which could be more easily applied and perhaps even transferred to novel situations, was seen as a winning option in the eyes of educators before any real evidence was available regarding its impact on learning in the classroom (Hung, 2011). With that enthusiasm, PBL spread not only to other medical schools, but also other disciplines and education levels including primary education. However, the excitement over the potential of the approach was defused once investigations into the effectiveness of PBL curricula began to deliver inconsistent results. Several meta-analyses emerged to aggregate the results into a more meaningful picture, but although each analysis was more sophisticated than the last, they could not explain the heterogeneous results found among primary studies (e.g. Albanese & Mitchell, 1993; Vernon & Blake, 1993; Walker & Leary, 2009).

What could be at fault when the approach has such theoretically sound promise? Various theories have been proposed regarding the potential culprits underlying the heterogeneous outcomes. Some have attributed the inconsistencies to the design of the

PBL problems, others have pointed to the functioning of the tutorial groups, and still others placed blame on weak study designs, inappropriate assessment tools, and a lack of robust data beyond the medical field. Furthermore, given that PBL has been interpreted in a myriad of ways since its inception, but little data has been available to show how these adaptations impact learning, researchers have voiced a call-to-action to examine the fidelity with which PBL is actually implemented (Grant & Glazewski, 2017). After all, it is difficult to attribute outcome results to an intervention without knowing how it was enacted in practice (O'Donnell, 2008).

Fidelity of implementation is a critical piece of research pertinent to examining any novel intervention or instructional method (Durlak & Dupre, 2008). It allows investigators to more comprehensively appraise and weigh the impact of an intervention based on the way it was enacted. This is imperative given that research shows that more often than not, theory differs from practice. Teachers do not passively adopt new curricula, but in many cases, implement it in ways, which conform to their circumstances and needs (Rogers, 2003), such as lack of administrative backing, accountability pressures, and time constraints (Nolder, 1990). Teachers' pedagogical beliefs coupled with their prior knowledge and experience, have been shown to influence how curricula are taken up and delivered as well (Kirk, 1988). It has been shown that pedagogical orientations, such as learning facilitation or knowledge transmission, produce very different learning environments, which could consequently impact student achievement (Gow & Kember, 1993).

Implementation fidelity in the case of PBL is of particular importance, given its unique design. Especially at the K-12 level, the role transformation that takes place between the teacher and the students, which differs greatly from the roles they hold in a traditional learning environment, is key to PBL’s design. For teachers, embracing this more facilitative rather than directive role, as well as being able to surrender to the at times, ambiguous nature of PBL driven by student inquiry, have been reported as some of the key challenges teachers face when implementing the method (Grant & Hill, 2006). In addition, teachers have voiced doubts regarding their ability to actually transition students to become more active agents in their own learning process (Gallagher, 1997). They have also expressed concerns over being able to effectively assess student learning in PBL (Brinkerhoff & Glazewski, 2004), which could impact how they assist their students in overcoming challenges as they grapple with difficult material. Atop of teachers’ pedagogical beliefs and concerns over their ability to implement aspects of PBL properly, teachers also face accountability pressures. This induces fear of not covering an adequate amount of content in the classroom and consequently, drives many teachers to assume a more teacher-directed role and proceed down a more traditional path even when implementing PBL (Moust et al., 2005). Given the coalescence of these various factors, it can be inferred that PBL implementation is likely to vary from teacher to teacher. This variability may have an impact on student learning, since just as Barrows indicated, when instructional methods diverge from the original PBL design, it becomes unclear which learning objectives are actually being met (Barrows, 1986). On the other hand, the reality is, that in multifactorial environments, such as the classroom and school, effects of PBL are likely to be inadvertently influenced by a myriad of factors, which makes attributing success or failure solely to a PBL intervention, limited in scope (Norman & Schmidt, 2000). Unfortunately, the true nature of PBL implementation has not yet been extensively studied to be able to make conjectures regarding this matter.

The majority of research efforts that have focused on determining which factors could influence student learning in PBL, have concentrated on identifying the most effective tutor characteristics, as well as tutors' approaches toward students. Establishing whether the tutor should be a content expert or novice began a lengthy debate in the medical literature with some researchers pointing to content expertise as essential to PBL facilitation (Dolmans et al., 2002; Schmidt et al., 1993; Schmidt & Moust, 1995), while others indicating that content expert tutors could actually have a negative impact on the PBL process (De Volder, 1982; Silver & Wilkerson, 1991). Most recently, a meta-analysis on the subject, determined that no differences could actually be found between the impact content expert and novice tutors have on student learning (Leary et al., 2013). The authors pointed out that facilitative practices of tutors might actually play a more critical role in student achievement than tutor content expertise.

Perhaps it is a combination of factors that come together to make facilitating PBL effective? Schmidt and Moust (1995, 2000) suggested that PBL tutors should possess related content-knowledge, but even more importantly, social congruence or a disposition to engage with students in a more informal and empathetic manner. The authors proposed that these two qualities were interrelated aspects of cognitive congruence or the ability of the tutor to communicate with students in a way that could be easily understood by them. The results of research by Schmidt and Moust (1995, 2000), as well as Chng, Yew, and Schmidt (2011, 2015), showed that the combination of tutors' subject-matter expertise, social congruence, and cognitive congruence had a significant impact on student achievement in PBL.

Other lines of research have attempted to elucidate the specifics of tutors' facilitative practices in order to better understand how to support in practice the learning goals PBL was designed to address. For instance, by focusing their efforts on tutor – student interactions, Hmelo-Silver and Barrows (2006) and Gilkison (2003) outlined facilitative strategies that tutors could adopt to help raise students' critical awareness, promote their construction of evidence-based arguments, encourage their self-directed learning, and be able to more successfully facilitate student group processes. Alternatively, Willem De Grave and colleagues (1999) identified the extent to which tutors' facilitative practices were actually found helpful by students. Students found the most effective tutors to be those that assisted them in the elaboration and integration of knowledge, those that stimulated interaction among group members, held students accountable, as well as directed their learning process. Interestingly, among tutors that were rated as average-performing, students preferred the ones stressing the learning process, rather than content. De Grave et al. (1999) added that the differences in how tutor profiles exemplified the four aspects of facilitation could be taken to represent the conceptions teachers hold about teaching and learning, indicating whether their behavior aligns more with a knowledge transmission or a learning facilitation model of teaching.

The alignment between tutors' theories regarding teaching and learning and their actions in the classroom while implementing PBL, have recently begun to be studied. Although preliminary, this work is beginning to shed light on the variability with which PBL is implemented across classrooms and points to the importance of examining enactment. Through contrasting case studies, Pecore (2013) and Liu, Wivagg, Geurtz, Lee, and Chang (2012) exemplified ways in which teachers enacted PBL units with secondary and middle school students, respectively. What they found was that although teachers reported their beliefs to be in line with the educational philosophy undergirding PBL, classroom observations depicted a different picture. Half of the teachers modified their instruction accordingly, whereas the other half did not. High-alignment teachers were able to shift the traditional teacher/student dynamics to allow students to be more in control of their own learning as they facilitated students' progress. Low-alignment teachers had difficulty relinquishing such control and proceeded to implement PBL in a teacher-directed manner. Implementation also differed along other dimensions such as student group size, timeframe of unit enactment, as well as use of provided, adapted, and self-created materials (Liu et al., 2012).

It is clear from these portrayals that PBL is not enacted equally in all cases and therefore, not all students will have the same learning experience with PBL. These differences could have a profound effect on student learning, yet unfortunately, no data is currently available in the PBL literature to provide insight as to how different implementation styles influence student achievement. It has been suggested that some adaptations to PBL implementation might in fact be necessary for younger learners in order for the process to be more developmentally appropriate and cognitively feasible (Pedersen, Arslanyilmaz, & Williams, 2009), but given the lack of evidence, it is impossible to make informed decisions as to which modifications would assist students, yet sustain an environment that would allow for the deep, contextual learning that PBL was designed to offer.

In order to begin to fill this void in the PBL literature, the aim of this study is to provide extensive accounts of PBL enactment across various middle schools and through rigorous, systematic data collection and analysis compose teacher implementation profiles. These profiles would reveal the most prevalent instructional patterns in PBL implementation, which the PBL community has long been seeking. Moreover, through this investigation, teacher implementation profiles would be linked with student outcome data, which would delineate which profiles tend to be associated with greater student outcomes. The results would elucidate which PBL practices might be most beneficial for use with younger learners.

Chapter 2: Review of Relevant Literature

Problem-Based Learning

Problem-based learning (PBL) is a constructivist approach to teaching, which places the student at the center of learning and promotes the development of skills demanded by the 21st century, such as problem-solving, critical thinking, and collaboration. It provides a comprehensive learning environment, which is interdisciplinary in nature and contextualized within an authentic problem space. The work of students in PBL emulates that of practitioners that need to resolve ill-structured problems. Through this process, students have the opportunity to take ownership of their own learning and monitor their own progress, giving them the tools to become lifelong learners.

The PBL method originated at McMaster University Medical School in Canada in the later part of the 1960's. During this time, research on the clinical reasoning of medical students at McMaster pointed to the fact that they were unable to apply knowledge gained in the classroom to their clinical experiences (Barrows, 1986). In addition, students showed disinterest in their learning and displayed a lack of professionalism (Newman, 2005). Since the medical program was initially based on traditional views of learning driven by behaviorist theories prevalent at the time, the focus of instruction was on the transmission of a predetermined body of knowledge by teachers to students. Emphasis was placed on incremental, sequential learning, as well as repetition and memorization of material. Yet, evidenced by the results of research examining medical students' progress, there seemed a great disconnect between being able to learn in this manner and having the ability to apply such knowledge in practice.

Hence, the faculty at McMaster began to question its suitability for the preparation of medical professionals. As one of the members pointed out, “conventional methods of teaching probably inhibit, if not destroy, any clinical reasoning ability” (Barrows, 1996, p. 4).

With their growing malcontent, the health sciences faculty comprised of professors John Evans, Bill Spaulding, Fraser Mustard, Jim Anderson, Bill Walsh and others, set out to reinvent McMaster’s approach. The “case-study” method used in the business and law schools of Harvard inspired their new, preclinical curriculum (Mueller, 2008; Schmidt, 1993). They composed an array of patient cases presenting problems spanning the entire field of medicine. These became critical centerpieces for their vision of a curriculum, which focused on problem-based, self-directed learning, facilitated rather than directed by teachers (Mueller, 2008). Howard Barrows, who joined the faculty at McMaster in 1970, was the one to systematize the approach. Barrows became instrumental in advancing the method and ultimately, emerged as one of its leading advocates (Barrows, 1986; Newman, 2005; Schmidt, 1993; Walker & Leary, 2009).

According to Barrows (1986), the fundamental learning objectives of learning through PBL were to: 1) structure contextual, flexible knowledge, which would allow for easier recall and applicability of that knowledge in future settings, 2) develop critical reasoning skills, 3) develop self-directed learning and meta-cognitive skills, as well as 4) foster motivation for learning (Barrows, 1986). In addition, the intention behind the design was for students to experience a learning environment that emulated working within a community of practitioners, where students were given the opportunity to collectively diagnose patients’ medical issues and devise courses of treatment. The emphasis here was on students developing a comprehensive, interconnected knowledge base that would allow them to understand the underlying processes of illnesses, rather than acquiring discrete pieces of information that they later had difficulty applying in real life settings (Mueller, 2008).

In order for the learning objectives delineated above to be achieved, Barrows (1996) outlined six essential characteristics of PBL based on the McMaster model. He posited that:

1. Learning should be student-centered
    - Students are to be the agents of their own learning; they ought to be the ones to determine what it is they know and understand about the problem at hand and what additional information they need to seek out. They should be the ones to devise a plan of action and only depend on the teacher as a peripheral guide on this journey.
2. Learning should occur in small student groups
    - Students should work in groups of 5-9 and switch groups, as well as the facilitator, upon completion of a unit.
3. Tutors should act as facilitators or guides
    - The tutor should facilitate student learning rather than transmit information. Instead of lecturing or providing students with answers, the tutor should play the role of a metacognitive coach and probe student thinking to help them realize the gaps in their own understanding. Over time, students should continue the metacognitive work on their own in

addition to challenging each other's thinking and the tutor's presence should fade.

4. Problems should form the organizing focus and stimulus for learning
    - Students ought to be presented with an authentic problem scenario (e.g. a simulated patient in the case of medical education), which would become the impetus for their learning. This would require students to identify what they already know and the information they need to seek out.
5. Problems should be the vehicle for the development of problem-solving skills
    - Problems should be structured in a way that would emulate how they would materialize in a real-world setting.
6. New information should be acquired through self-directed learning
    - Through independent research and collaboration with classmates, students should acquire knowledge in a manner similar to that of practitioners in the field. Students should discuss, evaluate, and debate their findings and understanding.

Based on these six essential characteristics, the McMaster team designed the PBL cycle or tutorial process (Hmelo-Silver, 2004), which commences with students being presented with an ill-structured problem, usually a patient case, as in the field of medicine, or other complex dilemma requiring an intervention. In small groups, students discuss what information they can derive from the scenario and share knowledge they already possess relevant to the circumstances at hand. They propose preliminary hypotheses, determine learning issues, and set objectives they need to address. They divide the responsibility of attaining additional information required to solve the matter among the group members. Then, individual members employ self-directed learning (SDL) skills in order to identify relevant resources and information the group may find pertinent to the problem. After gathering this information, the group members reconvene, share their findings, integrate them into what they already know and re-examine their hypotheses in light of their new understanding. They continue this cycle until they complete the unit. As a culminating activity, the students partake in peer and self-evaluation and reflect on the PBL process, as well as the evolution of their understanding (Savery & Duffy, 1995).

Throughout the PBL cycle, the teacher or PBL tutor facilitates student learning. Although PBL has received some scrutiny about being an approach that provides students with minimal to no guidance (Kirschner, et al., 2006), the role of the tutor is in fact an integral part of PBL (Hung, 2011). It has been argued for instance that, “the single greatest factor that influences the success of a PBL program is the facilitatory skill, knowledge and ability of the teacher” (Jones, 2006, p. 487). The tutor is the guide that assists students as they maneuver through this complex learning environment. Instead of transmitting knowledge to students as is typical in traditional instruction, the tutor steers students toward self-directed learning by modeling appropriate meta-cognitive strategies, as well as reasoning processes (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005; Hmelo-Silver et al., 2007). The tutor scaffolds student learning by posing probing questions to assess their understanding and to gauge the direction in which they are heading (Barrows, 1988). The line of questioning also serves to promote certain cognitive activities essential to deep learning, such as elaboration, integration, and application of knowledge (De Grave, Dolmans, & van der Vleuten, 1999). In addition, the tutor plays a key role in how the tutorial groups function; hence he/she monitors group processes, progress (Barrows, 1988), and stimulates interaction between students (De Grave, et al., 1999). Throughout the PBL cycle, the responsibility of the tutor is to provide students with the tools to be able to manage similar problems encountered in the future on their own, hence, as in any apprenticeship model, the close guidance by the tutor fades overtime and students have an opportunity to take greater ownership of the PBL process (Hmelo-Silver & Eberbach, 2012).

Theoretical Underpinnings of Problem-Based Learning

In order to better understand how PBL's characteristics and the PBL cycle support the attainment of the learning objectives defined above, one must turn to the theoretical basis underlying the design of the PBL learning environment. Historically, PBL arose as an approach to learning at the time of the cognitive revolution in psychology (Schmidt, 1993) and was further supported by modern theories of learning that placed emphasis on the social and cultural aspects of knowledge construction (Bransford, Brown, & Cocking, 2000). It exemplifies a shift in the field of education, which embraced the integration of these different theoretical perspectives previously considered independent of one another, to more comprehensively explain the process of learning and inform the practice of teaching (Cobb, 1994; Derry, 1996; Greeno, Collins, & Resnick, 1996; Mason, 2007). Hence, PBL can be described as a constructivist approach that stems from cognitive science and sociocultural theory (Duffy & Cunningham, 1996; Hmelo & Evensen, 2000; Yew & Goh, 2016).

Constructivism is a broad term that encompasses an extensive array of views (Duffy & Cunningham, 1996) and surplus of definitions (Fosnot & Perry, 2005). As Ernst von Glaserfeld (1997) stated, it is “a vast and woolly area in contemporary psychology, epistemology, and education” (p. 205). It stems from the field of cognitive science, the later work of Jean Piaget, the sociocultural work of Lev Vygotsky, the work of Jerome Bruner, John Dewey, and Jane Lave, just to name a few (Duffy & Cunningham, 1996; Fosnot & Perry, 2005). Although, there is no one single definition of constructivism, those that adopt the view in education according to Duffy and Cunningham (1996), Savery and Duffy (1995) and Bruning et al. (2004), tend to agree on the following three principles:

1. Learning is a process of constructing rather than acquiring knowledge.
2. The learner is an active agent in constructing such knowledge as he/she interacts with the environment and participates in social interactions with others.
3. The role of instruction serves as support for constructing knowledge rather than conveying it.

One way to further unpack and organize constructivist views is to take a look at the two main perspectives driving the ideology: cognitive and sociocultural (Cobb, 1994; Palinscar, 1998). In basic terms, cognitive constructivists place emphasis on the individual in the learning process and focus on the internal changes of knowledge structures within the individual, whereas, sociocultural constructivists underscore the “social origin of cognition.” As such, their interest lies in how social interactions and participation in cultural activities influence meaning making (Cobb, 1994). In a different explication of the two theories, Sfard (1998) summarizes the cognitive perspective as the *acquisition metaphor*, which indicates that one acquires knowledge and internalizes it as his/her own, after which, it can be applied, transferred, and shared. The sociocultural approach, on the other hand, can be depicted as the *participation metaphor,* by which learning can be understood as a process of engaging in the activities of a community as one inches closer to becoming one of the community's members (Mason, 2007).

Information-processing theories explain what underpins the cognitive constructivist position to a great extent (Greeno et al., 1996; Schmidt et al., 2009). From this perspective, learning is the result of the reorganization and the enhancement of individuals' knowledge structures or semantic networks, which are web-like organizations of concepts and their interrelations in long-term memory (Schmidt, 1993). Semantic networks provide a lens through which one comprehends all that is around him/her. The quality and vastness of the structures determine what a person is able to attend to and the level of accuracy and depth of understanding one acquires (Rumelhart & Ortony, 1977; Schmidt, 1993). Encoding specificity or in other terms, contextual dependency, is also a key aspect of learning from this perspective (Schmidt, 1983; 1993). It emphasizes the significance of context in encoding new information, as well as in retrieval of prior knowledge. The activation and retrieval of prior knowledge is central to expanding one's understanding. Hence, when new information is encountered, cues in the environment (context) stimulate applicable knowledge structures and the more connections one can make, the greater potential for his/her comprehension (Schmidt, 1983). Moreover, engaging in the process of elaboration strengthens and expands semantic networks. Thus, when one has the opportunity to elaborate on information, it can be better understood, processed, and retrieved (Anderson & Reder, 1979). Another important feature of cognition is epistemic curiosity, which supposes that individuals are innately motivated to learn new information interesting to them, solve problems, and resolve any discrepancies they may identify between their current understanding and new information they encounter (Litman, 2008). When epistemic curiosity is aroused, learners are more likely to increase study or processing time and consequently, improve their learning (Schmidt, 1993). Instruction and the design of learning environments can play an integral role in promoting these cognitive principles to improve student learning, but different methods vary in the degree to which they are able to accomplish this, hence student learning may or may not reach its full potential depending on the instructional approach (Mayer, 1982).

The other perspective guiding constructivism stems from sociocultural theory and is heavily influenced by the work of Lev Vygotsky (1978). Although Vygotsky was interested in the individual's cognitive development, he emphasized the role of social interactions and culture as the driving forces in the construction of knowledge (Phillips, 1997). His effort to highlight the situative perspective of learning has greatly impacted the views of social constructivists (Palincsar, 1998). From this view, knowledge construction is situated and context specific. Furthermore, learning is viewed as the process of enculturation into a community of practice, which entails active participation in the collective activities of the community and the appropriation of the community's discourse, beliefs, reasoning, and cultural practices (Brown, Collins, & Duguid, 1989; Greeno et al., 1996). As such, knowledge is not necessarily possessed by the individual, but it is distributed among the community (Mason, 2007; Savery & Duffy, 1995). Learning is seen as being strengthened as newcomers partake in communal activities and as their roles advance from being legitimately peripheral to becoming more central (Lave & Wenger, 1991). As Hmelo and Evensen (2000) stated, knowledge construction "is not an accumulation of information, but a transformation of the individual who is moving toward full membership in the professional community" (p. 4). A way that beginners advance within the community is through apprenticeship where their progress is guided by a more knowledgeable other (Collins, Brown, & Newman, 1989; Greeno, et al., 1996) who models ways of being and thinking to the learners and coaches them as they attempt the practices themselves. Another key element crucial in this process is derived from Vygotsky's learning theory, which emphasizes the importance of evaluating learners' zone of proximal development and underlines the importance of scaffolding novices' learning as they attempt to advance their understanding and practices (Cole, 1985).

The PBL learning process is grounded in both, the cognitive and the socio-cultural perspectives. Given that the problem scenario is what students are exposed to at the outset of the PBL process, students' initial examination of the problem spurs the activation of their prior knowledge and epistemic curiosity. The retrieval of students' prior knowledge assists in focusing students' learning and aids in comprehension of the new material (Schmidt, 1993). Through discussions in small groups, students are able to elaborate on their thinking and understanding, and as they participate in this active processing of new information they are able to store and organize it in long-term memory in a way that enhances future retrieval. As students reapply their knowledge back to the problem scenario, engaging in an exchange of ideas with their classmates, the opportunity arises to experience a state of perturbation (Dewey, 1938), which motivates them to reevaluate their understanding and seek out more information to advance their comprehension (Savery & Duffy, 1995). This continuous, active processing leads to a restructuring of students' knowledge and enhancement of their cognitive structures.

Constructing such a comprehensive semantic network of concepts, principles, and processes in the context of an authentic problem space may also aid students in transferring what they learn to similar, but novel situations.

Moreover, as students engage in these collaborative deliberations in an attempt to understand the problem and find a solution, their work begins to mirror that of expert practitioners. PBL allows students to learn as an outcome of being enculturated into a community of practice, rather than by learning isolated concepts and procedures devoid of authentic grounding, as is often the case with traditional instruction. The way students reason about the problem at hand and the language or other symbolic tools they use to communicate and advance their ideas are elements of the culture into which they are entering (John-Steiner & Mahn, 1996). Hence, students are able to internalize new information within this culturally relevant space, which makes meaning making more relevant and meaningful. Throughout this process, students' learning is guided and scaffolded by their tutor as in an apprenticeship model. The line of questioning and prompting the tutor employs, exhibits the type of expert behavior the students need to adopt. Furthermore, as students become more skilled and confident in their roles as the PBL cycle unfolds, the tutor gradually retreats and allows for the students to proceed with even greater autonomy, showcasing the transformation of novices toward their more central position within the professional community.

Similar Instructional Approaches

Given its theoretical foundation, PBL shares the platform with other instructional methods such as project and case-based learning, as well as anchored instruction, just to name a few. These methods promote a more constructivist view of learning and share features with PBL, such as using complex problems or scenarios to enhance learning. In project-based learning, a term often used interchangeably with problem-based learning (Hung, 2011; Walker et al., 2015), students explore real-world problems and work collaboratively with peers on extensive projects that usually result in a product (e.g. presentation) based on their investigations. In case-based learning, students are presented with a scenario portraying a problematic situation, which they need to analyze, come to comprehend, and provide a solution or a course of action. Anchored instruction also revolves around a case depicting a dilemma and is usually presented to students in video format. The case or “anchor” is designed to spur the beginning of a new topic, provide a starting point for discussion and knowledge sharing, as well as offer students a point of reference which they can revisit as they try to better understand the topic (Bransford et al., 1990, Hmelo-Silver, 2004).

Although all of these methods support active and inquiry-based learning, they vary with regard to the level of student autonomy they offer, as well as the purpose the problem serves in instruction (Hmelo-Silver, 2004). For example, project-based learning tends to be more scripted in nature, requiring students to follow set procedures, whereas students in PBL have the freedom to set their own learning goals and follow a more authentically derived learning trajectory. The problem in PBL is designed to specifically align with particular curricular goals, while the doing of the project in project-based learning can take center stage, diminishing the curricular focus (Brush & Saye, 2017). The end deliverable tends to be the focus of project-based learning and a single correct solution is usually the aim, while the process of working through the problem is central to PBL and identification of various viable solutions is encouraged (Savery, 2015). In case-based learning, students are likely to receive content instruction before or after the case is presented (Walker et al., 2015) as well as materials needed to solve the case (Williams, 2005), which reduces their opportunity for free inquiry. The intended goal is for them to solve the case by recalling previous knowledge or experience solving similar cases (Aamodt & Plaza, 1994; Garvey et al., 2000). This is in stark contrast to PBL, where students are presented with the problem before any instruction takes place and are responsible for acquiring resources to help them understand the problem and strive to arrive at a solution on their own. In anchored instruction, although the purpose of the “anchor” as the impetus for learning parallels the presentation of the ill-structured problem in PBL, overall, the approach depends much more on the teacher’s involvement in leading the learning and providing content material. Hence, although problem-based learning shares similar features with these approaches, the fact that students are immersed into the situation “cold” and the instructor plays an assistive role in guiding rather than directing their process, sets this approach apart. These differences are not trivial, but relate specifically to the vision PBL’s founders had for the type of learning experience they wanted to create for their students and the affordances such learning was to bring about based on PBL’s theoretical grounding.

Various Problem-Based Learning Models

The kind of problem-based learning that has been depicted thus far has been based on the original, McMaster model put forth by Barrows and Tamblyn (1976). However, PBL in practice has taken on various forms since its inception. The term ‘problem-based learning’ has often been “misused and misapplied” according to Davis and Harden (1999, p.130) and as Barrows (1986) stated, once PBL gained popularity, the term became an umbrella term for numerous teaching approaches that happened to use problems in their instruction, similarly to the instructional approaches discussed above. In addition, problem types began to vary in their format and level of difficulty. Barrows (1986, 1996) pointed out that these alternative instructional methods and problem types, addressed different learning objectives than those, which the method was originally designed to address and did not adopt the theoretical assumptions PBL was founded upon. He cautioned that "educational sacrifices" might be the result of adopting these modified approaches, since they could impact the type of learning fostered. Consequently, Barrows (1986) composed a taxonomy of different methods that were often referred to as PBL, but were its variant, in order to shed light on how these methods compared qualitatively to the originally proposed model.

The taxonomy exemplified the extent to which PBL learning objectives would be met given the coalescence of three variables: 1) the type of problem students are presented with, 2) the manner in which information related to the problem is offered, and 3) the degree to which the learning environment is teacher vs. learner centered.

Lecture-based cases are described to be solely teacher directed. Here, students are lectured about relevant content before they are presented with a case to be solved. The case is offered with all pertaining facts in tack, thus this method does not allow for much of free inquiry on the part of the learners. According to Barrows, this approach does not directly promote any of the educational goals PBL is to foster.

Case-based lectures are yet again, solely teacher led, but the difference in this approach is that students are presented with cases at the beginning and are then followed by lectures focusing on information pertaining to the cases. Thus, students are challenged to leverage their prior knowledge to begin to understand the problem and reconstruct that knowledge as more information offered by the teacher becomes available. This method is rated as second poorest with regards to the learning objectives it supports.

The case method is the first in the taxonomy to afford students the opportunity to self-direct their learning, since students are presented with a case to examine and conduct research in advance of any discussions related to solving it. Once class convenes, the teacher plays the role of a facilitator to guide student thinking. Although this method allows for more hypothetico-deductive reasoning on the part of the students, as in PBL, it is limiting due to the fact that the case is still presented to students as a comprehensive package.

The modified case-based method begins to challenge students to a greater degree, since it provides them with only select facts related to the case. Students are then engaged with problem formulations that most often require them to either construct a limited course of action or choose from actions and decisions delineated for them. They engage in this inquiry in small group settings, where a tutor guides their efforts. Although, the opportunity for the development of critical reasoning skills is heightened through this method, it is still limited due to the fact that students are not conducting a comprehensive investigation nor determining all possible courses of action.

The problem-based method offers students simulated patient files, where they are able to fully engage in hypothesis generation and data collection in order to diagnose the problem at hand. Tutors help students draw on prior knowledge to construct new meaning of the information they acquire through free inquiry and assist them in identifying any misconceptions they may possess that could impede their learning.

The closed loop or reiterative problem-based approach takes the problem-based method a step further and requires that students continue to reexamine the evidence and reasoning they initially mustered in light of the patient problem simulation. This reiterative process challenges students to reassess the current state of their understanding, as well as their prior conceptions and problem-solving skills. This reevaluation may spur a need for more self-directed learning in order to fill gaps in student understanding and to help them compose a more exhaustive solution to the problem. Barrows underlined that the closed-loop or reiterative problem-based method is most likely to foster the type of learning required to attain the learning objectives the original PBL method was intended to promote (Barrows, 1986). Hence, other variants might not produce the same depth of learning and yield the same results.

Although Barrow's taxonomy was an effort to set the original PBL method apart from different approaches that had adopted the name problem-based learning, others proceeded to depict alternative PBL models, which in their view, offered flexibility and accommodated various circumstances while encapsulating the benefits of learning through PBL. These diverging viewpoints in PBL research: the pure-PBL perspective, which adheres to the original McMaster model (e.g. Barrows, 1996; Dolmans et al., 2005; Maudsley, 1999; Schmidt & Moust, 1995), and the hybrid-PBL perspective (e.g. Davis & Harden, 1999; Duch, 2001; Savin-Baden, 2003), which welcomes adaptations driven by the demands of particular disciplines or specific curricular goals (Savery, 2006), point to the complexity of understanding PBL in research or for the purpose of implementation. Below are examples of some of the hybrid-PBL models that have been depicted in the literature.

Harden and Davis (1998) proposed a similar taxonomy to that of Barrows, but focused on slightly different elements in delineating their continuum. Whereas Barrows' taxonomy concentrated on the type and format of the problem used, as well as the extent to which the learning environment was student or teacher centered, Harden and Davis explained their classification as based on the problem and the type of learning the problem afforded. Founded on the 1960's principles of programmed learning, the eleven stages of the continuum they proposed progressed from information acquisition (lectures about concepts and principles) to problem-based learning (concepts and principles embedded in cases students were to decipher). According to Davis and Harden (1999), PBL should not have to be viewed as an all or nothing approach, but one "offering a range of options" from which teachers can choose from.

Savin-Baden (2000) described five PBL models that arose from the views and pedagogic beliefs of instructors incorporating the approach into their practice. They were driven by the faculty's positions on what constitutes knowledge and their roles as educators. The models: PBL for epistemological competence, professional action, interdisciplinary understanding, transdisciplinary learning, and critical contestability, represent a similar continuum to that of Barrows' taxonomy in exemplifying an increase in student-centeredness, student content exploration and knowledge construction and a decrease in teacher-centeredness and the propositional view of knowledge.

Duch, Groh, and Allen (2001) proposed four PBL models, which arose from faculty endeavoring to implement PBL in undergraduate courses. The models they comprised were: the medical school model, floating facilitator model, peer tutor model, and the large class model. Although the medical school model closely resembled the original McMaster model, the authors determined that certain adaptations to the original model were necessary based on various factors in undergraduate programs such as class size, course objectives, intellectual readiness of the students, instructor preferences, and availability of graduate teaching assistants or peer tutors. Therefore, the additional three models, although using an ill-structured problem as a stimulus for learning, only provided the level of facilitation that large class settings led by a single instructor allowed (unless additional assistance was provided by peer tutors). In such settings, the models were also more teacher-centered with instructors providing students content to ensure that enough material was covered.

As can be seen by the various models of PBL that have emerged overtime, as enthusiasts of the approach began to shape and mold it to their needs, the exactness of what the method stood for began to disintegrate. As Barrows (1993) pointed out, the term problem-based learning has much less precision now than it did when it was originally proposed. Given the example of Barrows' taxonomy, the various modifications could alter the learning goals of PBL and student learning in unpredictable ways. But before any conjectures regarding this matter could be made, a summary of the research on the effectiveness of PBL needs to be reviewed.

Effectiveness of Problem-Based Learning

The belief in the potential of PBL to provide an environment that could cultivate deep, meaningful learning was so strong that the dissemination of the approach across medical schools and other disciplines occurred without any substantial evidence pointing to its effectiveness over traditional methods (Neville, 2009; Savery, 2006). Eventually, the intrigue over PBL evolved into a desire to examine its impact on student learning and hence, several meta-analyses surfaced to offer a synthesis of the effects of PBL compared to traditional instruction (e.g. Albanese & Mitchell, 1993; Berkson, 1993; Colliver, 2000; Dochy, Segers, & Van den Bossche, 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Newman, 2005; Vernon & Blake, 1993). The following section highlights the research on PBL's effectiveness in higher education, as well as the K-12 level.

Problem-based learning in higher education. One of the first meta-analyses to appear comparing learning through PBL versus conventional instruction in medical education was conducted by Albanese and Mitchell in 1993. The authors reviewed 17 studies conducted between the years 1972 and 1993. They categorized and listed study results based on effect sizes (ES) and *p* values. In order to identify how PBL students compared to their counterparts on science knowledge assessments, the authors reviewed the results of the NBME – (National Board of Medical Examiners) – Part I examination, as well as other basic science tests. Overall, the results indicated that PBL students perform less well on these assessments than students taught via traditional instruction. However, these results showed great heterogeneity. Six out of the nine studies analyzed pointed to traditional students outperforming PBL students, but only three of these were statistically significant at the .05 level. The ESs for overall science exam scores ranged from -1.00 to +.27. The authors pointed out that two out of the three studies, which focused on examining the effects of a more directed form of PBL, obtained positive results (Blumberg et al., 1990). This, they theorized, might be an indication of the fact that students require more tutor involvement and specific content exposure in order to improve their scientific content knowledge. For the purpose of examining students' clinical ability, NBME II, as well as other clinical examination results were utilized in the analysis. In general, the findings pointed to PBL students outperforming traditional students, but the results were not as definitive as expected and the authors identified "complexity in the data" (p. 60) as a possible culprit. The meta-analysis also provided results comparing PBL and traditionally taught students on their clinical ratings by residency supervisors and alike. These findings indicated more positive reviews of PBL students with ES ranging from .02 to .51. In their concluding remarks, the authors cautioned against drawing any absolute judgments based on the review due to the murkiness of the available data, weak study designs, and potentially confounded outcome measures (Albanese & Mitchell, 1993).

Vernon and Blake (1993) analyzed 22 studies conducted 1970-1992, including four studies also reviewed by Albanese and Mitchell (1993). The authors took a statistical approach to synthesizing the results and conducted several analyses to understand the differences between PBL and conventional students' learning outcomes. In order to assess academic achievement or basic science knowledge, they parsed apart the results of the NBME I from other knowledge assessments. The measures of the NBME I involving 28 samples showed traditional students significantly outperforming PBL students. However, a vote count allowed for five additional samples to be included in the comparison and equalized the groups. In addition, as was the case with knowledge evaluation results presented by Albanese and Mitchell (1993), the variability among these results was statistically significant. The authors pointed to findings from New Mexico and Michigan State Universities in particular, with the former showing all negative ES values and the latter, obtaining all positive results. In order to compare students' clinical abilities, Vernon and Blake looked at the results of students' clinical performance ratings and tests, as well as their clinical knowledge exam scores (e.g. NBME II). The results of students' clinical performance revealed that PBL students did significantly better than traditional students. The results of students' clinical knowledge exams, which were available from only four reports, revealed a slight trend in favor of PBL students, but the outcome was not statistically significant. Although Vernon and Blake's methodology in conducting these analyses was much more rigorous than that of Albanese and Mitchell (1993), the general conclusions they reached were similar. Students in traditional programs outperformed PBL students on basic knowledge assessments, although these results showed great heterogeneity, requiring further investigation. PBL students excelled on evaluations of clinical performance and clinical knowledge. Similarly to Albanese and Mitchell, Vernon and Blake pointed to the weaknesses in the original data, which warrants proceeding with caution when drawing conclusions from the review.

In 2000, Colliver took a critical stance when reviewing the 1993 meta-analyses mentioned above and also included additional research that emerged 1992-1998. He criticized the level of sophistication of the previous work and summarized the findings as showing PBL having little or no effect on student achievement. He pointed out that the results of Vernon and Blake's (1993) analyses of basic knowledge assessment, clinical knowledge assessments and clinical performance assessment only showed weighted means of $d = -0.18$, $d = 0.08$, and $d = 0.28$, respectively, which could be attributed to medical students' pre-existing differences and not the intervention method employed. He came away with a similar critique of the additional studies he reviewed and determined that the magnitude of effectiveness regarding students' knowledge or clinical performance is unsatisfactory for an intervention of this caliber. He concluded by saying that PBL's theoretical basis is inadequate and lacks clear connection between concepts, observables, and outcomes. He also added that, "the basic research is contrived and ad hoc, using manipulations to ensure results" (p. 264).

Dochy, Segars, Van den Bossche, and Gijbels (2003) conducted a more extensive, and rigorous statistical meta-analysis, which included 43 empirical studies and moved beyond the medical field to include research from other disciplines in tertiary education for the first time. They examined not only the differences in knowledge and skills gained by PBL students and students in traditional classrooms, but also potential moderator variables that could influence the outcomes. Their knowledge and skills analysis closely echoed the results found by Albanese and Mitchell (1993) and Vernon and Blake (1993), with PBL students underperforming on knowledge related assessments compared to students in traditional programs but outperforming them on measures of skill or knowledge application. The authors pointed out that the negative knowledge-related outcomes were impacted by two outlier studies. Once the outlier studies were removed, there were no significant differences between the groups. Moreover, the moderator analysis revealed that students' level of expertise, period of retention, and type of assessment also influenced the outcomes. The authors found that students' expertise was related to the variation in effect size for both knowledge and skills results (although the skills outcomes remained positive for PBL students even after this was taken into account). With regard to the retention period, the authors discovered that the knowledge gaps between PBL and traditional students during the first and second years of school dissipated when students were assessed beyond this period. Hence, the authors reasoned that although PBL students might have acquired slightly less knowledge, they retained it more successfully. In addition, the way students' knowledge and skills were assessed seemed to play a part in how well they scored. It appeared that the more suited the skills assessment was to adequately evaluate students' skills, the greater the PBL effect. Although not as concrete, assessments of knowledge that focused on retrieval of information rather than recognition (e.g. multiple-choice exams) tended to benefit PBL students, signaling the potential of PBL students possessing a more organized knowledge base. The authors also found quality of study design, as well as scope of implementation (curricula wide or single-course PBL) to be possible mitigating factors in evaluating the results. Dochy et al.'s report, being the first major undertaking in an attempt to parse out various factors that may be influencing PBL results, points to the complexity of examining the differences between PBL and conventional students' achievement and the work that still needs to be had.

Following Dochy et al.'s assessment findings, Gijbels, Dochy, Van den Bossche, and Segers (2005) undertook a meta-analysis attempting to further unpack the influence of assessment on PBL vs. conventional learning outcomes. They divided the types of assessments used to evaluate student achievement into three levels of knowledge structures based on Sugrue's model of cognitive components of problem solving (1995). Level one encompassed concept comprehension, level two covered the understanding of principles that link concepts, and level three included the application of concepts and principles (the required conditions and procedures). Overall, the authors found that the levels of knowledge structures proved to be influential when measuring the effects of PBL on learning. According to a vote count, students that learned in a PBL environment did considerably better on levels two (principles) and three (application) than students from traditional settings and the difference between the groups on level two reached statistical significance. With regard to level one (understanding concepts), the analysis revealed no statistically significant differences between the students. Although Gijbels et al.'s efforts in grouping the assessments according to Sugrue's model provided some invaluable insights as to the potential factors influencing the outcomes, the authors also pointed out that other moderators might still need to be identified given the heterogeneity of effect sizes across the primary studies.

The most recent and comprehensive meta-analysis to date was conducted by Walker and Leary (2009). The aim of their meta-analysis was to fill prevailing gaps in the literature and offer insight as to the differences found in student achievement based on various disciplines of study, knowledge assessment levels, implementation methods, and problem types. The authors determined that PBL students did as well as or better than traditional students overall, but these findings approached a small effect size and showed a lack of homogeneity. Interestingly, PBL students were more inclined to outperform traditional students in disciplines other than medicine, such as teacher education and other social science fields. When knowledge acquisition was analyzed, the authors' findings nearly mirrored those of Gijbels et al. (2005) mentioned above, where PBL students performed better on principle and application level outcomes and showed no difference on conceptual understanding when compared to traditional students. In terms of problem types, the authors discovered that design problems and strategic-performance problems showed much stronger effect sizes than diagnosis-solution problems (the problems most prevalent in medicine), which was a surprising finding given that these types of problems are further away from PBL according to a problem type continuum by

Jonassen (2000). In terms of implementation methods employed, the authors pointed to the incredibly limited number of studies available, only 2 out of 82 studies actually described the method used. Those two studies claimed to use the closed-loop approach to PBL, defined earlier, and obtained a moderate level effect size in favor of PBL. Although Walker and Leary were able to provide novel insights explaining the various factors that may influence PBL findings, they did underline that there was still a lack of homogeneity among the results on the whole even after the data was parsed several ways. The authors suggested that additional research is still required in areas other than medicine. They also advised that more clearly identified particulars of implementation, such as PBL method and problem type, are necessary in order to obtain a clearer picture of PBL's impact on student learning.

Problem-based learning in primary education. When compared to the availability of research at the higher education level, research on the effectiveness of PBL in K-12 settings is incredibly scarce. Nevertheless, there are several individual studies that represent the work examining the impact of PBL versus traditional instruction on student achievement with younger learners. For example, Gallagher and Stepien (1996) conducted a study to counteract arguments that learning in PBL produced lower factual knowledge gains than conventional instruction. Sophomores in a gifted high school underwent a yearlong American studies course via traditional or PBL instruction. There were four teachers that participated in the study that taught anywhere between 1-3 sections of the course, but only one teacher employed the PBL method in one of his two sections. In this single PBL section, PBL was utilized intermittently throughout the academic year, which translated to its implementation approximately 50% of the time.

During the PBL activities, dilemma problems based on historical events were the focus of students' challenges. Assessment of students' knowledge took place at the beginning and end of the academic year via a multiple-choice standardized exam mirroring a typical American studies summative test. The results revealed that there were no significant differences on factual knowledge acquisition between students exposed to conventional or PBL instruction. Although PBL students achieved slightly larger gain scores, these results were not statistically significant. The authors concluded that given their findings, PBL should not be viewed as detrimental to students' factual knowledge acquisition. However, the results of this study should be interpreted with great caution given the limitations of study design, such as the single PBL section implementation. In addition, the fact that PBL was enacted only half of the time and the problems used were dilemma type problems should also be noted. Furthermore, since the study was conducted with gifted students, it is limited to that population.

In 2000, Hmelo, Holton, and Kolodner conducted a study to examine if learning through PBL would help students understand the functioning of the lungs better than conventional learning. They developed a three-week PBL unit in collaboration with classroom teachers that challenged sixth-grade students to design artificial lungs. They also included a comparison classroom that was taught the same material via traditional instruction. In order to identify student-learning gains, they administered a pre/post short-answer test, as well as a drawing task that asked students to explain the lung's processes. The results showed PBL students obtaining greater learning gains on both assessments than students taught via conventional methods, however, PBL students possessed some misunderstandings at the completion of the unit. The authors indicated that the duration of the unit would need to be extended in the future to provide students with ample time to tackle such a complex problem. They also emphasized that although the implementation was done with great effort, there were areas in which it could be improved to more adequately support student learning and progress. In conclusion, Hmelo and colleagues (2000) suggested that the original PBL model might have to be adapted to better suit the needs of younger learners, thus various scaffolding approaches and direct instruction might need to be employed by teachers to assist students as they grapple with such difficult material.

Araz and Sungur (2007) examined the effects of traditional versus PBL instruction on eighth grade students' learning in a five-week science unit on monohybrid cross and genetic diseases. Learning in the PBL classroom followed a typical, iterative PBL cycle where small groups of students worked collaboratively to solve ill-structured problems as cases while the instructor played the role of a facilitator. In the comparison classroom, although students were bound to cover the same material, the instruction was teacher-led, lecture, and textbook based. After the five-week unit, students took a Genetics Achievement Test, measuring knowledge comprehension and performance skills, as well as a Test of Logical Ability, assessing formal reasoning ability. Results showed PBL students scoring significantly higher on the Genetics Achievement Test (Araz & Sungur, 2007) than their counterparts, indicating a more integrated knowledge base. Interestingly, the Test of Logical Ability (Tobin & Capie, 1981) analysis revealed that there was a significant relationship between reasoning ability and assessment outcomes. Generalization of these results should be done cautiously though, due to limitations of the study, including the small sample size and the multiple-choice test reaching internal consistency reliability coefficient of only 0.63.

Drake and Long (2009) designed a pilot study to determine if PBL was more effective than direct instruction at increasing fourth grade students' science content knowledge, transfer of problem solving skills, and retention of knowledge overtime. Over the course of two weeks, students in a PBL classroom and a comparison classroom participated in daily lessons aimed at developing their understanding of magnetism and electricity. The authors found that students in the PBL classroom gained significantly more content knowledge than their counterparts when assessed immediately after the completion of the unit, but there were no differences between the groups on post testing conducted four months after the intervention. Post instruction, PBL students appeared to exemplify less stereotypical views of scientists than the comparison students based on the results of a Draw-a-Scientist Test (Mason, Kahle, & Gardner, 1991). Interviews conducted with a subset of students immediately after the unit and four months later, which required them to solve a science problem, resulted in PBL students providing more problem-solving strategies and extensive responses. Although these findings are promising, the authors did point to the small sample size being an issue in determining statistical differences between the groups. Therefore, the study would need to be replicated on a larger scale to achieve greater validity.

The research on PBL in K-12 settings is promising, but as can be seen, it is incredibly limited. Although PBL appears to have a positive influence on student learning, the various research design limitations and the variability across PBL models and duration of interventions, make it difficult to draw any significant conclusions. In order to make any concrete statements regarding PBL's effect on student learning in K-12, more research is required. However, the cumulative evidence regarding PBL's effect on learning at the higher education level and the evolution of that research provides invaluable insight. In the earlier meta-analysis reports, it appeared that PBL students underperformed on basic science knowledge evaluations but excelled on skills and application assessments when compared to their counterparts (Albanese & Mitchell, 1993; Vernon & Blake, 1993). However, with research efforts that sought to further unpack the findings, the results based on the type of knowledge being assessed (conceptual, principle, application) began to paint a more comprehensive picture and more adequately depicted PBL students' achievements (Gijbels et al., 2005; Walker & Leary, 2009). Potential moderator effects, such as students' level of expertise, period of retention, assessment type, quality of study design (Dochy et al., 2003), problem type (Walker & Leary, 2009), as well as the scope and method of implementation (Dochy et al., 2003; Walker & Leary, 2009) were all found to influence PBL students' results. Although all of these complexities have been unearthed, a problem, which was echoed throughout the meta-analyses (Gijbels et al., 2005; Walker & Leary, 2009) and still remains, is the heterogeneity among the primary study outcomes. This puzzling phenomenon still needs to be uncovered.

Some suggest that given the vast interpretations of PBL, one cannot know exactly, which learning objectives are actually being met (Barrows, 1986; Walker & Leary, 2009). Variation in the design of PBL activities could also be at fault for the discrepancy among findings (Hung, 2009). The type of problems used during the tutorial could influence the kind of learning that is stimulated (Jonassen & Hung, 2008), which was evident in Walker and Leary's meta-analysis results (2009). The level of group functioning has also been identified as a potential factor in influencing outcomes, since the dysfunction of a group could significantly sabotage the prospects of PBL (Dolmans et al., 2001).

Given the multitude of potential underlying reasons for the heterogeneity among the results of primary studies in higher education, researchers have begun to underscore the importance of shifting the focus of PBL research from investigating its effectiveness to examining the elements of the PBL process (Hung, 2011) and the varied influence they may have on learning. In particular, many have voiced a call to action concerning the need for the examination of PBL enactment (Dolmans, De Grace, Wolfhagen, & Van der Vleuten, 2005; Hung, 2011; O'Donnell, 2008; Pedersen, Arslanyilmaz, & Williams, 2009; Ravitz, 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009). Dolmans and colleagues (2005) have argued that, "Due to poor implementation of PBL, the learning process does not stimulate students towards constructive, self-directed, collaborative, and contextual learning" (p. 735). Successful facilitation of PBL still needs to be delineated (Strobel & van Barneveld, 2009) in order refine and improve how it is implemented in various contexts (Dolmans et al., 2005; Pedersen et al., 2009; Ravitz, 2009). Amidst all the theorizing, one thing is certain, attributing the results of PBL effects research to the method or design of the learning environment is problematic if the implementation is unknown (O'Donnell, 2008). Therefore, it is pertinent to examine the fidelity with which PBL curricula are enacted across classrooms.

Fidelity of Implementation

Fidelity of implementation generally refers to how closely an intervention is enacted when compared to its intended design (Carroll et al., 2007; Dane & Schneider, 1998; O'Donnell, 2008; Scheirer & Rezmovic, 1983). Measuring fidelity provides an assessment of a study's internal validity to help determine if study outcomes are a product of the intervention studied or other extraneous factors (Dane & Schneider, 1998; Durlak & DuPre, 2008; Gresham, 1989; Scheirer & Rezmovic, 1983). Without obtaining such evidence, investigations into the effectiveness of curricula may be considered "flawed and incomplete" (Durlak & DuPre, 2008, p. 340) and refinements to the design or implementation made difficult (Carroll et al., 2007; Scheirer & Rezmovic, 1983).

The study of implementation is a complex undertaking, but literature on best approaches to implementation has been evolving over the past few decades as a result of a "science to service" movement (Fixsen, Naoom, Blasé, Friedman, & Wallace, 2005; Ogden & Fixsen, 2014). This movement arose out of concern over the less than successful incorporation of evidence-based programs into practice (Fixsen et al., 2005). Although various models exist to assist with conducing assessments of implementation fidelity, a common practice is to focus evaluation efforts on factors that are structural and those that are process related (Gersten et al., 2005; O'Donnell, 2008). Structural components encompass such elements as adherence and duration or time allocation to the implementation of an intervention. These elements are intended to provide an objective measure of surface fidelity (Gersten et al., 2005), indicating which intervention components were implemented and how much time was devoted to their enactment. Process components are more subjective in nature and address the quality of the delivery of an intervention, participant responsiveness or level of engagement, and program differentiation (Dane & Schneider, 1998; Durlak & DuPre, 2008; Gersten et al., 2005; O'Donnell, 2008). Structure components simply provide an indication as to what aspects of an intervention were realized, while process components, usually captured through classroom observations, exemplify how well an intervention was employed (Harn, Parisis, & Stoolmiller, 2013). There is evidence to suggest that although process components or the quality of implementation may be more difficult to reliably measure, it is more directly linked to student outcomes (Gersten et al. 2005; O'Donnell, 2008) and can better explain why an intervention was successful or not (Harn, Parisis, & Stoolmiller, 2013).

However, the concept of what successful implementation means or looks like is a point of contention in the literature. Some believe that if implementation of an intervention strays from its original design, it may offset its effects (Mihalic, 2004). Others argue that perfect implementation is unrealistic (Durlak & DuPre, 2008). After all, there are various factors that come into play when an idealistically designed intervention is brought into the context of real life. For example, research has shown that teachers do not passively adopt new curricula, but often implement it in ways, which conform to their circumstances and needs (Rogers, 2003). Systemic issues such as lack of administrative support, accountability pressures, time constraints, and shortage of resources can influence the degree to which an intervention is implemented with integrity (Nolder, 1990). In addition, teachers' prior knowledge, past experiences, and self-efficacy may impact how curricula are taken up as well (Carroll et al., 2007; Kirk, 1988).

Furthermore, it has been shown that implementation fidelity can be influenced by the beliefs teachers hold regarding teaching and learning (Durlak, 2010). It has even been suggested that it is more likely that an intervention will be implemented with greater fidelity, if teacher beliefs actually match the theoretical underpinning of an intervention (Durlak, 2010; Durlak & DuPre, 2008). This is of no surprise, since research on the matter has shown that the beliefs teachers hold, and as such the learning goals they set, dictate what instructional strategies they employ and what supports they provide their students (Schoenfeld, 1998). Gow and Kember (1993) declared that based on teachers' conceptions of teaching and learning, two pedagogical orientations can prevail: learning facilitation and knowledge transmission. These orientations influence teachers' instructional practices, as well as the design of student learning environments (Gow & Kember, 1993). They impact the expectations teachers have of their students and dictate the type of engagement they afford them (Paris, Wasik, & Turner, 1991), which in turn, influences how students learn (Porter, 2002). Classrooms with an emphasis on learning facilitation are more likely to promote deep, meaningful learning, whereas classrooms with a focus on knowledge transmission support superficial understanding and memorization (Gow & Kember, 1993).

Moreover, research points to the fact that often times, the pedagogical approaches teachers report using differ from what they practice in class, which makes examining quality of instruction through classroom observation important (Davis, Petish, & Smithey, 2006; Hutner & Markman, 2017; Veal, Lloyd, Howell, & Peters, 2016). Since teachers' personal conceptions of teaching and learning may at times be inaccurate (Rando & Menges, 1991), a great deal of research has focused on uncovering the differences between teachers' beliefs regarding their instructional practices (*espoused theories*), and what they actually do in class (*in use theories*), which has pointed out discrepancies between the two (Argyris, Putnam, McLain, & Smith, 1985; Strauss, 1993).

However, what has also been observed, has been the fact that some teachers make conscientious decisions about modifying curricula in order to attune it to their students' needs (Harn et al., 2013). In these cases, although implementation fidelity could be considered less than optimal, student outcomes show to benefit from such adjustments (Simmons et al., 2007). The dilemma in such instances then becomes not what is the ideal measure of fidelity, but what is the ideal measure of fidelity for those particular contexts in order to achieve the most beneficial outcomes (Durlak & DuPre, 2008, Fishman et al., 2013).

Ideally, if implemented as designed, PBL should follow a constructivist ideology and engage students in authentic, collaborative learning (Gijselaers, 1996; Park, Ertmer, & Cramer, 2004; Pedersen et al., 2009). Its open-ended, ill-structured problem design should challenge students to develop flexible knowledge and critical thinking skills. Throughout the process, students should also be able to acquire meta-cognitive tools and become self-directed in their learning (Hmelo & Barrows, 2006; Hung, 2009). In order to foster such learning however, an instructor needs to embrace a more student- rather than teacher-centered approach (Brush & Saye, 2000) and take on the role of a guide that strategically facilitates student learning rather than disseminates information (Gijselaers, 1996; Hmelo & Barrows, 2006).

However, embracing such a role and its responsibilities, as well as being able to surrender to the at times, ambiguous nature of PBL, have been reported as some of the key challenges teachers face when implementing the method (Grant & Hill, 2006). In addition, instructors have expressed concerns over covering an adequate amount of content, which consequently, drives them to assume a more teacher-directed role in the classroom (Moust et al., 2005). They have also acknowledged concerns over their ability to effectively assess student learning in PBL (Brinkerhoff & Glazewski, 2004) as well as transition students to become more active agents in their own learning process (Gallagher, 1997). Students on the other hand, have reported having a difficult time with this role change, especially if their past experiences had been predominantly teacher directed (Ge & Land, 2003). It has also been shown that due to students' lack of domain-specific knowledge and self-regulatory skills, students are often unable to solve the problem they are presented with on their own (Cho & Jonassen, 2002) and tend to struggle with identifying, gathering, and synthesizing information needed for the task (Pederson & Liu, 2002).

There may be a myriad of variables, which influence the implementation of PBL and although the true nature of PBL implementation has not been extensively studied, the following section paints a picture of research that has begun to reveal the type of influence the tutor or teacher can have on learning through PBL in higher education, as well as the K-12 level.

Research On the Impact of the Tutor in Problem-Based Learning

Tutor characteristics. A great deal of research at the higher education level has focused on whether a teacher is better suited to facilitate student learning in PBL as a content expert or a content novice (Hmelo-Silver & Barrows, 2006; Maudsley, 1999). Content expert tutors are usually faculty specializing in the area of study, whereas content novices are most often faculty whose concentration lies in areas unrelated to the PBL problem topic or higher-level students. Identifying which tutor characteristics are most likely to foster student learning has undergone great debate (Chng, Yew, & Schmidt, 2011).

Some research has reported that content expertise is an important component of PBL facilitation (Dolmans et al., 2002; Schmidt et al., 1993; Schmidt & Moust, 1995). Students have even expressed an appreciation for the tutors' knowledge and found working with an expert to be a reassuring experience, especially in the context of an ill-structured environment (Feletti et al., 1982). However, a considerable amount of literature has pointed to the fact that content experts can interfere with student learning in certain respects. Subject-matter experts are likely to interject too much of their own knowledge into what is supposed to be a student-driven initiative (De Volder, 1982; Silver & Wilkerson, 1991). They tend to take a more directive role in comparison to their non-expert counterparts, speak more frequently and offer content-explicit responses to students' questions rather than promoting student-directed inquiry (Silver & Wilkerson, 1991). Students have also been reported to more heavily rely on content-expert tutors and actually elicit subject-matter information, study topics, and resources from them (Schmidt & Moust, 2000).

Alternatively, content-novice tutors have been found to be equally as effective as content-expert tutors at facilitating PBL (De Volder, De Grave, & Gijselaers, 1985; Moust & Schmidt, 1994). Research shows that since they are not content experts, they place greater emphasis on the process of PBL, which is an attribute rated most favorably by students (De Grave et al., 1995). Moreover, a recent meta-analysis of research on the topic by Leary and colleagues (2013) concluded that no difference could be found between the impact content expert and novice tutors have on student learning. The authors also referenced the work of Chng and colleagues (2011), stating that the facilitative practices of the tutor in PBL may play a more critical role in student achievement than tutor content expertise.

Schmidt and Moust (1995) suggested that for tutors to be effective in facilitating student learning in a PBL environment, they should not only possess related content-knowledge, but also, social congruence. Social congruence is a disposition of the tutor to engage with students more informally and in an authentic and empathetic manner, aiming to foster a comfortable environment for the open exchange of ideas (Chng, Yew, & Schmidt, 2015; Hmelo-Silver & Barrows, 2006). The authors proposed that these two qualities were interrelated aspects of cognitive congruence, the ability of the tutor to communicate with students in a way that could be easily understood by them. The authors advocated that cognitive congruence was a key factor to impact students' learning.

Schmidt and Moust conducted several studies examining the interplay between content knowledge, social congruence and cognitive congruence to determine how they influenced student achievement (e.g. Schmidt & Moust, 1995, 2000). They were able to determine that tutors' expertise and social congruence directly affected tutors' cognitive congruence, which consequently influenced the other factors in their model. Thus, the level of cognitive congruence had an impact on small group functioning, which in turn, influenced self-study time and students' intrinsic interest. Self-study time showed an effect on students' level of achievement. In addition, the tutors' subject-matter knowledge had a slightly negative effect on self-study time, but a slightly positive one on students' outcomes. The results of the study allowed Schmidt and Moust to reinforce their stance that although subject-matter expertise is an important quality of a tutor, the way that tutors approach their students and the climate they establish in the classroom is just as significant. Ultimately, PBL tutors should exemplify a combination of these characteristics.

Most recently, Chng, Yew, and Schmidt (2011, 2015) were able to replicate Schmidt and Moust's (1995, 2000) results to show that tutors' subject-matter expertise, social congruence, and cognitive congruence had a significant impact on student achievement in PBL. In addition, in their 2015 study, they advanced Schmidt and Moust's research by more specifically investigating the impact of tutor's social congruence on students' process and outcomes and grouped tutors based on their level of social congruence, while still including an assessment of their content expertise and cognitive congruence. Besides confirming the overall effect of all three characteristics, they found that tutors' behaviors had a more profound impact on academically average students as compared to students with above or below average achievement. This finding is particularly important when considering the many different contexts and academic levels PBL is implemented in and the sort of adjustments that might be required in facilitating PBL in order for younger or lower achieving students to benefit from the approach.

Facilitative strategies. In order to determine what facilitative strategies tutors employ as they guide student learning, Andrea Gilkison (2003) undertook the study of discourse between tutors and students during a PBL tutorial. She employed a linguistics framework in analyzing the observations of two PBL teams, which helped her identify a number of tutoring approaches that she grouped into three categories based on the influence they had on student progress. The category, *Raising Critical Awareness*, included exchanges identified as *elicitation, re-elicitation,* and *prompting*. Gilkison defined this selection of tutor strategies as ones aimed at stimulating the group discussion "to a higher cognitive level." *Facilitating the Group Process* consisted of *refocusing, facilitation, evaluating, summarizing,* and *giving feedback.* This category of interventions was meant to keep the students focused on the task and their learning goals, as well as keeping the group process moving smoothly. *Directing Learning*, which the author noted, did not arise often during the observations, was comprised of *informing,* and *directing learning.* These tutor interjections were aimed at providing students with facts, procedural directions or tutor ideas and most often, signaled the culmination of discussion.

Along the same lines, Cindy Hmelo-Silver and Howard Barrows (2006) focused on the exchanges between tutor and students to shed light on the intricacies involved in fostering student-centered learning. The facilitator in this case was Howard Barrows. Videos of Barrows' PBL implementation from two classes were extensively analyzed in order to identify the facilitative strategies he used aimed at attaining PBL learning goals he delineated. The analysis revealed that although, Barrows used open-ended questioning to address the majority of the learning objectives, he did employ some specific strategies such as: urging students to provide explanations, stimulating them to generate and evaluate their hypotheses, prompt them to make explicit connections between their evidence and claims (including the construction of visual representations), and urging them to check their understanding and progress, so that they could identify their learning issues and subsequent learning goals. He also engaged in summarizing and re-voicing student ideas to make student thinking visible (including the incongruity of their understanding), as well as to legitimize and include the voice of all students, subtly influence the direction of discussion, and move the group along.

Tutor profiles. Another area of research that is beginning to emerge has attempted to compose more macro level tutor facilitating profiles in order of identify the variability with which PBL is implemented and the impact that may have on students. For example, in their investigation, Willem De Grave and colleagues (1999) were able to identify different tutor profiles as a result of students' ratings of their tutors' behaviors according to four dimensions of the Tutor Inventory Profile (TIP) questionnaire (33-item, five-point Likert scale). The four dimensions were aimed at determining the extent to which tutors assisted students with elaboration, integration of knowledge, stimulated interaction, student accountability, as well as directed students' learning process. Given the results of the TIP, the authors were able to determine, which tutor profiles were considered more or less effective. Students rated the most effective tutors as being high on all four dimensions of the instrument (considered 'high-performing tutors'). And among the 'average-performing tutors', students preferred the ones stressing the learning process, rather than content. The authors also pointed out that the differences in how tutor profiles exemplified the four dimensions of the scale represent the conceptions tutors may hold about teaching and learning, such as knowledge transmission or learning facilitation.

Pecore (2013) set out to examine how teachers' beliefs in constructivist principles aligned with their teaching practices as they implemented a PBL unit in science. The study provided comparative case studies of four secondary teachers from three different schools. Teachers implemented a two-week PBL unit, which focused on the classification kingdoms of living organisms, where students were appointed the role of taxonomists and had to grapple with the complexity of designing a classification system. The results of their Constructivist Learning Environment Questionnaire revealed all four teachers possessing constructivist beliefs in the high to high-intermediate range (with senior teachers reporting slightly higher alignment than novice teachers), but data from the observations and interviews diverged from this picture. Principles of constructivism appeared to be more in-line with two of the teachers' classroom observations and interviews, but not the other two. The high and low alignment cases each consisted of a senior and a novice teacher. The high-alignment teachers modified their instruction to incorporate aspects of PBL they took up during their professional development workshop. They made specific changes to shift the teacher/student dynamics and allow students to be more in control of their own learning. The low alignment teachers' classrooms were not as suited to take on the implementation of the PBL unit. Although one of the teachers attempted to incorporate aspects of PBL into her lessons, the overall nature of her instruction was not adapted to fit a constructivist scheme. She proceeded with the PBL unit utilizing traditional materials formulated in past years of teaching the same topic. Classroom management issues overran the class of the other low-alignment teacher and did not possess the foundation to enact a constructivist curriculum such as PBL. Both low-alignment teachers had a difficult time relinquishing control to the students; hence students in each class did not take ownership of their own learning. The author concluded that although all teachers reported to believe in constructivist views on learning, not all of them led their classrooms in-line with such beliefs. Therefore, across these classrooms, PBL was not enacted equally and not all students were able to partake in a constructivist form of learning, leaving the reader to wonder how this may have impacted students' learning outcomes.

Pedersen, Arslanyilmaz, and Williams (2009) posited that adaptations to PBL curricula, and more specifically PBL assessment materials, are quite likely to occur because teachers can struggle incorporating curricular materials stemming from a social constructivist perspective if their practices had been mainly traditional in nature. Hence, the researchers set out to examine teachers' assessment practices, as well as reasoning behind their choices, while they enacted a PBL unit. Teachers implemented a computer-based PBL program called Alien Rescue (Pedersen, Arslanyilmaz, & Williams, 2009) in their sixth-grade, science classrooms over the course of three weeks. Although they were provided all of the curricular materials, including assessment tools, they were able to choose which materials they used. They were also able to modify those materials and create additional ones if they felt they were necessary. The results of the study indicated that although teachers believed in the value of formatively assessing students throughout their participation in Alien Rescue, they often incorporated traditional style assessments, which were not in line with the constructivist nature of PBL. These adaptations were done in part due to the pressures teachers felt from administrators and parents to prepare students for standardized tests and present a multitude of objective scoring of students' progress. Teachers also believed students needed to be graded to help keep them on track and provide them with extrinsic motivators. The authors of the study concluded by saying that although, they do not know if these adaptations could be "lethal mutations" as defined by Brown and Campione (1996), they do know that they “change the nature of PBL, making it more teacher-directed” (p. 245).

More research examining how teachers enacted the Alien Rescue program comes from a study by Liu, Wivagg, Geurtz, Lee, and Chang (2012). With an understanding of the need for elucidating what PBL implementation looks like at the K-12 level, these researchers provided detailed depictions of how four teachers implemented this computer-based PBL module in their sixth grade science classrooms and how they adapted it to their students’ needs. The authors chose two pairs of contrasting case studies of teachers to showcase different implementation styles. According to the authors, although the first pair of teachers taught at the same school and both expressed a belief in student-centered learning, the teachers implemented the PBL program very differently. One of the classrooms was teacher-controlled with a great deal of whole class instruction/lecturing and student independent work. The other class was primarily student-centered and more typical of a PBL learning environment. In this class, students worked collaboratively while the teacher took on the role of a tutor and helped to facilitate student learning, observing the groups and probing their thinking. The second pair of teachers taught at different schools with different student demographics. Approximately 40% of the students at one of the schools were economically disadvantaged and classified as at-risk, students at the other school did not face those challenges. The authors described the practices of the two teachers as quite opposite from one another with one teacher taking on a very hands-on approach and the other, a hands-off one. The hands-on teacher was observed regularly circulating the classroom checking on student progress, redirecting student questioning to the group or class, and probing student thinking. The hands-off teacher was observed mostly at her desk while students worked on the project. In this class, students worked in pairs and approached the teacher if they had questions. They were often asked to reference their Alien Rescue materials for answers. The authors concluded by saying that they observed great variability in implementation across classrooms when it came to teacher/student control, group size, timeframe of enactment, the use of provided, adapted, and self-created materials, as well as the availability of technology. Although, they ascertained that regardless of this inconsistency, the enactment of their PBL unit was "successful" for all teachers, they did not provide any student data to corroborate these claims.

Limits of the Literature

The fact that research efforts surrounding PBL have evolved to include the examination of the tutor's impact on the learning process instead of mainly looking at student outcome measures has begun to provide some answers, which the PBL community has long been seeking. The research on tutor characteristics provides some insight as to the qualities and demeanor of the tutor most beneficial for students. Investigations into the specific strategies used by tutors as they facilitate students through the tutorial may help refine PBL practices and offer concrete examples especially to those new to the approach. And research delineating tutor profiles or overall teacher enactment practices is beginning to shed light on the variability in PBL implementation efforts.

Although some inferences can be drawn from these research endeavors, most of the conclusions were derived from either self-report data or descriptive case studies. Research presenting tutor profiles, most pertinent to the examination of the fidelity of PBL implementation, is comprised of only a handful of studies based on only several teachers' classrooms. Furthermore, although the enactment descriptions are beginning to uncover how greatly implementation can vary among teachers, none of the studies venture to link student outcome data to teacher implementation profiles, thus providing no indication as to which profiles could actually be most beneficial for student learning in various contexts.

Hence, the research base is still quite limited and missing large scale, rigorous analyses looking at how teacher practices differ from class to class when implementing the same PBL program and the impact those differences may have on student learning. As fidelity of implementation research shows, examining implementation while paying attention to other meditating factors is key to understanding the effectiveness of a program. Therefore, this study aims to begin to fill this void within the PBL literature by examining teachers' implementation profiles as they enact a PBL simulation with their 7^{th} and 8^{th} grade students and determining how these profiles relate to those students' outcomes. A rigorous statistical analysis, combining both factor and cluster analysis will be employed to identify teacher implementation profiles. Subsequently, student assessment results will be examined based on which PBL implementation students were exposed to in order to gain insight as to how differences in implementation might impact student learning. Finally, teacher interview data will shed light on the mediating factors that played a role in implementing the PBL simulation.

Research Questions

The aim of this research is to address the following research questions:

RQ1.What implementation profiles emerge as teachers enact a PBL simulation in middle schools?

RQ2. After controlling for students’ pre-writing assessment scores, does implementation type have an effect on students’ post-writing assessment outcomes?

RQ3. What possible factors influenced the manner in which GlobalEd 2 was enacted?

Chapter 3: Method

The aim of this study was threefold. First, this investigation sought to determine what variability existed among implementation practices employed when a PBL simulation, the GlobalEd 2 project, was enacted. Second, implementation profiles were utilized as the independent variable in examining if differences in PBL implementation impacted student outcomes. Third, the study investigated factors that could have impacted fidelity of implementation of the simulation across classrooms. This study utilized a mixed-methods design**,** leveraging the affordances of both quantitative and qualitative methodologies to help explain the research questions (Tashakkori & Creswell, 2007).

This chapter will outline the methodology for this study, including context, study participants, simulation details, instrumentation, data collection procedures, and analysis methods.

Context

This study utilized pre-existing teacher and student data, gathered in the fall of 2014 as part of a larger study, the GlobalEd 2 project, a U.S. Department of Education: Institute of Educational Sciences Goal 3 grant (Brown, Lawless, & Boyer, 2013; Lawless & Brown, 2015). The GlobalEd 2 study was a randomized, controlled study, aimed at determining the efficacy of the GlobalEd 2 intervention and included a comprehensive assessment of fidelity of implementation through the measure of four distinct dimensions: adherence, quality, application time, and program differentiation.

This study focused predominantly on the quality dimension of GlobalEd 2 implementation. In addition, as part of the larger grant, two sections of each participating teachers' social studies class were randomly assigned to either the treatment condition (GlobalEd 2) or the control condition (normal education practice), however, for the purpose of this study, only teacher and student data from the GlobalEd 2 sections were used for analysis.

Participants

The teacher sample was composed of 53, 7th and 8th grade social studies teachers (33 female, 20 male). Twenty-eight of the teachers represented urban schools and 25 represented suburban schools. The sample was purposefully stratified in order to better reflect student diversity in schools across the nation. Teacher participants were divided by race (81% White, 11% Black/African-American, 4% Hispanic, and 4% Asian or Pacific Islander). Participants' reported years of teaching were distributed as follows: 6% less than 3 years, 51% 3-9 years, 29% 10-20 years, and 14% more than 20 years. In addition, 21% of the teachers previously participated in GlobalEd 2 and 79% were new to the program.

Students of participating teachers, who assented to be involved in GlobalEd 2, were included in this study. The student sample derived from the GlobalEd 2 condition was comprised of 998 students (519 female, 455 male, 24 undisclosed) with 535 of the students from urban schools in the Midwest and 463 from suburban schools in the Northeast U.S.. Student distribution at grade level was 525 seventh grade students and 470 eighth grade students. Student participants were divided by race (44% White, 13% Black/African-American, 29% Hispanic, 7% Asian or Pacific Islander, and other races/ethnicities).

Intervention: GlobalEd 2

GlobalEd 2 is an online, interactive, problem-based learning simulation, adapted from earlier work by Brown and colleagues (2003). It was developed over several years through a Goal 2, Institute of Education Sciences (IES) grant (Brown, Lawless & Boyer, 2008). In its current iteration, GlobalEd 2 is a part of a multi-year efficacy trial, an IES Goal 3 grant (Brown, Lawless, & Boyer, 2013; Lawless & Brown, 2015). The simulation utilizes an ICONS system originally developed by the University of Maryland (http://www.icons.umd.edu), which allows participants to role-play through complex scenarios in a closed, online environment.

GlobalEd 2 is situated in 7th and 8th grade social studies classrooms and allows students from different regions and of different socio-economic backgrounds to collectively investigate real world issues in an online environment over the course of 12 weeks. The project leverages social studies, a multidisciplinary platform, as a means to help students develop scientific literacy and an understanding of science in a more integrated and authentic manner. Through GlobalEd 2, students engage in simulated, international negotiations in which they collaborate to resolve global problems, such as fresh water scarcity, through the development of multi-classroom ("multi-national") agreements.

In GlobalEd 2, each participating classroom is assigned a country, which the class personifies throughout the simulation. Each country is also divided into four delegate teams that tackle the country's water scarcity problem from four distinct perspectives: environment, health, human rights, and economy. During phase 1 of the simulation, the research phase, students have four weeks to collaboratively conduct and synthesize research regarding their assigned country's concerns and policies related to fresh water scarcity. In addition, students gather information regarding the country's culture, geography, as well as political and economic standing, etc. At the conclusion of the research phase, delegate teams construct preliminary proposals delineating how the problem could be addressed and they invite the "global community" to join in their effort. They share these arguments electronically with the rest of the students in the simulation and begin the next phase of the project, the interactive phase.

Phase 2 or the interactive phase of the simulation spans six weeks and allows students to partake in synchronous (i.e. instant messaging) and asynchronous (i.e. email) online deliberations regarding the issue at hand. Student communication is text-based, designed to strip away factors that could impact participation, such as gender or race. It also offers students an opportunity to practice writing focused on scientific argumentation promoted through the project. Text-based exchanges allow teachers and project personnel to assess student understanding and progress. Throughout students' negotiations, communications are monitored and fostered by the simulation coordinator (Simcon). This is done in order to keep students on task, challenge their thinking, and maintain a diplomatic tone to their exchanges. The end goal of the interactive phase is for students from each of the special interest delegate groups to compose a comprehensive plan to address fresh water scarcity and to reach a multi-national agreement with another country in the simulation.

Upon completion of the interactive phase, students enter the two-week debriefing phase, where they reflect on their process and evaluate how their understanding and views changed over the course of the simulation.

According to Barrows' (1986) PBL taxonomy, the design of this PBL simulation would be considered a closed-loop or reiterative problem-based method, given the format of the problem presented (simulated problem scenario), the level of student autonomy or degree to which the learning environment is student-centered, as well as the reiterative process of examining current understanding in light of gathered evidence and the pursuit of additional information to more accurately and comprehensively address the problem posed. Barrows emphasized that this type of approach to PBL is most likely to foster the type of learning required to attain the learning objectives the original PBL method was designed to promote (Barrows, 1986).

Instrumentation

Classroom observations. During the 12-week implementation of the GlobalEd 2 simulation, teachers were observed weekly in their GlobalEd 2 classrooms. Observation data were collected via a computerized observation instrument adapted from Pellegrino, Goldman, Bertenthal, and Lawless (2007). The tool was designed to capture classroom practices and indicate the extent to which the practices followed the *How People Learn* (Bransford, Brown, & Cocking, 1999) framework. The framework stems from a synthesis of decades of research on the science of learning and offers recommendations as to the best instructional practices that can help develop and support deep learning. It emphasizes such instructional elements as student-centered practices that take into account students' background and prior knowledge, and provide students with opportunities for greater autonomy and self-directedness. It also promotes opportunities for student construction and organization of knowledge around central ideas of a discipline, as well as partake in joint negotiation of meaning and collaborative problem solving. The framework also underlines the importance of ongoing assessment, both on the part of the students and teachers, hence students develop an ability to monitor their own understanding and teachers identify knowledge gaps or misconceptions students possess to offer appropriate guidance. This framework and its theoretical basis are in line with PBL principles (Cox & Cordray, 2008; Massa, 2008) and therefore, the tool was considered a suitable match for this data collection effort.

The tool captures classroom behavior (e.g. student/teacher and student/student interactions), as well as other elements of the learning environment. The observation categories are as follows: classroom grouping (4 items), course ideas (10 items), instructor behavior (8 items), student behavior (13 items), community (11 items), assessment (10 items), materials/resources (16 items), and technology (9 items). The tool also allows for extensive field note taking. A screenshot of the tool can be viewed in Appendix A.

For each observation, classroom activities are captured in 10-minute episodes. During each 10-minute episode, observers take field notes for 5 minutes while they observe, after which they use the field notes to characterize the activities by checking off codes on the observation checklist under each category aforementioned. Once the observers complete the 5-minute coding segment, the episode is considered complete and the observers begin a new 10-minute episode. This cycle is repeated for the duration of the class. Once an observation is finished, the data is exported into Microsoft Excel. The format displays all of the field notes and codes chosen during each 10-minute episode per observation.

Project staff comprised of graduate research assistants at both research sites conducted the observations. Observers underwent a one-day, in-person, intensive training on the observation tool at each site. The training provided observers education regarding the theoretical basis of the observation tool and what it was designed to capture. Observers became familiar with all of the observation codes and procedures for coding each observation. The codebook can be found in Appendix B. Observers practiced coding several paper vignettes written out to illustrate hypothetical 5-minute coding episodes, as well as two 30-minute classroom videos. Group discussions were held regarding coding each observation segment in order to help observers gain a better understanding of the coding scheme. In order to assess observers' understanding of the coding scheme and establish inter-rater agreement, observers coded an additional 30-minute classroom video independently. Inter-rater reliability varied between $r = 0.70$ and $r = 0.83$ (median $r = 0.76$) using Holsti's method, an acceptable rate for data of this nature (Lombard, Snyder-Duch, & Bracken, (2002). If level of agreement was unsatisfactory, observers coded additional classroom videos independently and discussed discrepancies with the trainer.

Student persuasive essay task. In order to assess student learning gains in terms of scientific argumentation writing ability, as well as science and social studies content knowledge, a persuasive essay task was administered to students before the simulation began and immediately after it concluded. The persuasive essay task prompt can be found in Appendix D. Students were asked to respond to the prompt: "The world is in danger of running out of fresh water? Do you think this is true? Do you agree or disagree with this statement? Why?" The directions explicitly asked students to provide evidence and reasoning for the claim/s they were making, as well as encouraged them to incorporate their knowledge of water, science, geography and cultures to help compose their arguments. Students were provided 30 minutes to complete the writing task.

The persuasive writing task was evaluated according to a rubric adapted from McNeill & Krajcik (2006; 2008), found in Appendix E. The rubric focuses on identifying quality of argument chains composed of claims, supportive evidence, and reasoning. In addition, it requires an indication of the student's position, statement of opposition, the essay's overall organization, as well as the level of science and social studies content the student incorporates into the response.

Two independent raters, graduate students at each research institution, blinded to student identity, study condition, and time of administration, scored each of the student's persuasive essays. Raters underwent intensive training on the rubric at both sites, scoring multiple rounds of essays until at least 80% agreement was reached among raters. Two independent raters scored each essay. If both raters indicated the presence of a code, but their scores differed by one point, the average of the two scores was taken as the final score. If there was a discrepancy between the raters' views on the presence or absence of a code or the raters' scores differed by two points, a third rater provided additional scoring that resolved the dispute (e.g. the two closest scores among the three raters were averaged to provide the final score). Inter-rater agreement of at least 80% was maintained by requiring raters to code a set of 10 essays bi-weekly. Raters' individual scores were compared to the mode scores. If raters fell below the 80% agreement rate, they received feedback for improvement. Agreed upon scores on each element of the rubric were aggregated to provide a total quality essay score. Instrument reliability was measured by one-way random ICC and found to range from .649 (single measures) to .969 (average measures).

Teacher interviews. Post simulation, teachers participated in a semi-structured, in-depth interview, found in Appendix C. The interview was conducted via telephone and audio-recorded with teachers' permission. The length of the interview ranged from 30-50 minutes. The semi-structured format of the interview allowed for specific questions to be asked of all teachers, but also permitted for follow-up questions based on individual teachers' responses (Charmaz, 2006). The initial, open-ended questions were designed to elicit information about teachers' general teaching philosophies and assessment practices. Questions that followed were GlobalEd 2 specific. These questions began by inquiring about how prepared teachers felt to implement the simulation in their classrooms and what they did to ready themselves for its enactment. The subsequent questions were aimed at gathering information regarding if and how implementing GlobalEd 2 influenced their instruction and assessment practices, how they structured their classroom, as well as the extent to which they modified the GlobalEd 2 curriculum activities. The next section focused on examining the impact the simulation had on student learning from the teachers' perspective. Lastly, teachers were asked if they faced any challenges during implementation and if they had feedback on how the simulation could be improved in the future. Once interviews were completed, project personnel transcribed the interviews verbatim to ready the data for analysis.

Procedure

Participant recruitment involved reaching out to teachers that have participated in earlier iterations of the project, as well as informing additional teachers from local school districts about the opportunity to participate via email and social media channels. Although teachers volunteered to participate in the GlobalEd2 project, they needed to fit certain criteria in order to be eligible for the study, such as: teaching at least two sections of 7th or 8th grade social studies, two years of teaching experience in social studies, basic technology skills (email, Internet use), Internet access (in classroom or lab), availability for the GlobalEd2 professional development training, and fall implementation of the simulation. Teachers provided informed consent with the understanding that they could withdraw from the study at any point in time and would be compensated for taking part in the initial, as well as ongoing GlobalEd2 professional development to the extent of its completion. In addition to teacher consent, principal letters granting approval for teacher and student involvement in the project were also obtained.

The 7th and 8th grade students of participating teachers were asked to participate in this study. Students were informed that their participation was voluntary and that they would still be able to take part in all of the GlobalEd2 activities, even if they did not want to be involved in the data collection efforts. Student data was gathered only if both student and parental permission were obtained.

In the summer of 2014, new GlobalEd 2 teachers participated in a self-paced, online professional development aimed at preparing them to implement a fresh water scarcity simulation in the fall. Teachers had three-weeks to complete a number of different modules embedded with videos and assignments, which explained the intricacies of the simulation, as well as educated them on the principles of teaching and learning through PBL. The modules also addressed written scientific argumentation, assessment, as well as science and social studies content related to the problem of fresh water scarcity around the world. After completion of the self-paced portion of the training, new and veteran GlobalEd 2 teachers participated in a one-day, online, interactive PD session, where a discussion was held regarding teachers' past experiences with GlobalEd 2, as well as explanations of how the simulation was improved based on the feedback teachers offered in earlier iterations of the simulation. Subsequently, teachers participated in a pseudo-simulation that in a truncated manner mimicked what their students would experience. This experience was provided in order to help teachers better understand the simulation process and what it will require of their students. In addition to the summer PD, teachers continued to receive PD in the fall in the form of weekly newsletters with supplemental resources (i.e., podcasts, articles, rubrics) and guidance with implementation and with maintaining the simulation's trajectory. Project staff provided teachers with ongoing support by answering questions and helping teachers overcome any obstacles they faced during implementation.

In the fall of 2014, pre-assessments were administered before the simulation began. The writing assessment was administered first, followed by all other assessments in order to avoid contamination of the writing assessment by any content present in the other measures.

Before the start of the simulation, the two sections of teachers' social studies classes were randomly assigned to either the GlobalEd 2 treatment condition or the control condition (normal education practice). An external consultant, who was not associated with the project, conducted the randomization.

Once all of the pre-assessments were completed, the GlobalEd 2 simulation commenced. The simulation unfolded over the course of 12 weeks with at least three 50-

minute GlobalEd 2 sessions per week. Teachers were encouraged to follow the GlobalEd 2 curriculum according to the simulation timeline, but had some freedom in their choice of GlobalEd 2 activities, as well as in making modifications they saw fit for their students. Control classrooms followed their regular set curriculum over this timespan.

During the simulation implementation, GlobalEd 2 classrooms and control classrooms were observed once a week for one lesson period (approximately 50 minutes) each. Observations were scheduled ahead of time with teachers and occurred only on days during which GlobalEd 2 activities were implemented. Observers played a non-participatory role in the classroom and were instructed to remain as unobtrusive as possible.

Once the simulation was completed, post-assessments (mirroring pre-assessments) were administered to classrooms of students in both conditions, starting with the writing task first, followed by all other assessments.

Within a week of the finalization of the simulation, teachers participated in a semi-structured, in-depth interview about their and their students' experience with GlobalEd 2, as well as their views regarding teaching and learning in general. The interview was conducted by project staff via telephone and audio-recorded with teachers' permission. The length of the interview was approximately 45 minutes. The audio-recordings were later transcribed verbatim to prepare the interviews for data analysis.

Chapter 4: Analysis & Results

In order to answer the proposed research questions, a mixed methods design was undertaken. The quantitative aspect of the analysis was conducted with IBM SPSS 25 and involved reducing the number of classroom observation variables into fewer, meaningful components that could be clustered to reveal the predominant instructional profiles exhibited during GlobalEd 2 implementation. Subsequently, student outcomes were evaluated in light of teachers' instructional profiles derived from the cluster analysis. The qualitative portion of the analysis was performed with the aid of NVivo software and involved the analysis of teachers' post-simulation interviews in order to gain insight into the potential reasons for implementation differences.

Analyses Addressing Research Question 1

RQ1. What implementation profiles emerge as teachers enact a PBL simulation in middle schools?

Classroom observation data was analyzed with the aim of gaining a better understanding of the variability among approaches to PBL enactment and to inform the quality dimension of GlobalEd 2's implementation fidelity. First, the data was exported from the observation tool to a Microsoft Excel application. The format displayed all codes chosen during each five-minute episode for every observed lesson. Since the data was nominal, it was transformed into a matrix, which displayed a dichotomous indication of the presence or absence (1 or 0) of the code per episode per teacher in each row.

Data screening and preliminary analyses. In order to prepare the observation data for analysis, each five-minute observation segment was first examined for accuracy. Cases void of observation codes were considered entry error and were removed. The dataset was comprised of 2627 five-minute observation episodes. The episodes provided an indication of the presence or absence of codes per each five-minute segment for each teacher's observation. In order to represent the degree to which certain instructional characteristics were exhibited during implementation, the episodes were collapsed across same-day observations for each teacher, indicating percent occurrence of each variable/code per observation. The final dataset represented 531 GlobalEd 2 observations across 53 teachers. Teachers ranged in the number of times they were observed, between 7-12 observations with 76% of the teachers being observed 10 or more times throughout GlobalEd 2 enactment.

With regard to the observation variables/codes, the "Technology" and "Materials" categories of variables were removed from the dataset, since they were not the focus of the analysis. All instances where the "Other" code option was indicated were reviewed and recoded using the existing observation codes. All occurrences of "None" coding were also removed from the analysis, since the purpose of the codes was to ensure that observers accounted for every category even in instances where none of the items for a particular category were applicable during the five-minute observation event. The remaining codes were evaluated in terms of percent occurrence and were removed from analysis if coded less than five percent of the time (e.g. code: class consults outside expert – 1% occurrence). These codes are listed in Appendix F. A decision was also made to combine several codes into pairs if one or both codes had a low rate of occurrence, yet the combination of the two was deemed significant (e.g. code: student self-assessment – 6% and student peer-assessment – 5%). A list of code combinations can be found in Appendix G. The remaining 30 observation variables, see Table 1, were included in the analysis.

Table 1

List of Observation Codes Used in the Analysis

Grouping	Course Ideas	Instructor Behavior
Whole class / Large group Small group / Pairs Individual	Facts / Definitions Big ideas Procedures / Instructions Strategies Explicit connections between the above Behavior / Expectations Housekeeping / Class business	Direct instruction Coaching / Scaffolding / Modeling / Demonstrating Leading discussion Listening / Watching Talking to individuals / groups
Student Behavior	**Community**	**Assessment**
Listening / Note-taking Question / Response Discussion Independent work Research or project work Presenting ideas / findings Reflecting on own knowledge /skills and/or reflecting on group experience	Students share their ideas / conjectures Students react to each other's ideas Students help each other	Activities make students' knowledge visible Activities make students' reasoning visible Instructor responds to students' needs / Students questions or needs drive activity Instructor feedback about products / process Student self and/or peer assessment

The data were also examined for univariate and multivariate outliers. Univariate outliers were detected by first inspecting boxplots indicating outlying cases, reviewing the Extreme Values table, as well as examining case values, transformed into standardized scores, for exceeding a score of ±3.29 ($p < .001$, two-tailed test), as recommended by Tabachnick and Fidell (2007). There were 16 cases identified as outliers with relation to the teacher "Leading discussion" variable, 14 cases related to students "Reflecting on own knowledge /skills and/or reflecting on group experience" variable, 14 cases related to student "Self/peer assessment" variable, and 7 cases related to students "Presenting" variable. Furthermore, even though the data were not normally distributed, detection of multivariate outliers was performed by identifying chi-square values produced with Mahalanobis distance that were found to be less than $p < .001$ (Tabachnick & Fidell, 2007). Seventeen cases were identified as multivariate outliers. Each univariate and multivariate outlier case was inspected in greater detail. All instances indicated a preponderance of certain behaviors/activities for teachers during particular observation days. Since this reflected the variability in teacher practice, the cases were not eliminated from analysis.

Given the nature of the data where certain instructional practices were exhibited, while concurrently, others were not (e.g. whole class instruction versus small group project work), the observation tool variables did not meet the assumption of normality. This was evidenced by varying skewness and kurtosis indices, as well as significant results on the Kolmogorov-Smirnov test across all variables. In addition, as recommended by Tabachnick and Fidell (2007), given the large sample size (531 cases), histograms for each variable were visually inspected to confirm the lack of correspondence of the distributions to the bell-shaped curve. Moreover, bivariate scatterplots were examined for several pairs of variables to test the assumption of linearity, however, mixed results were obtained, indicating a violation of the assumption for some of the variables. Nevertheless, variable transformations were not pursued in order to retain the true nature of the data and because of the exploratory nature of this study.

Principal components analysis. As a means to reduce the raw observation data, principal components analysis (PCA) was conducted. Principal components analysis is a multivariate analytical technique that helps to reduce the number of variables in a data set based on their interrelatedness (Jolliffe, 2002). It is commonly used in education settings for the purpose of finding meaningful subsets of variables and for data reduction purposes (Kane, Taylor, Tyler, & Wooten, 2011; Sawada et al., 2002). In the analysis, the original variables that are collinear in nature are transformed into a set of several principal components that are mostly independent of each other (Field, 2009). The components are then ordered with the first few encompassing the majority of the variance in the data set (Jolliffe, 2002).

A principal components analysis (PCA) with Promax rotation was run on the 30 observation variables, which identified teacher and student behaviors while the GlobalEd 2 curriculum was being implemented. Promax rotation, an oblique technique, was chosen since the components were theorized to correlate. The factorability of the 30 observation variables was examined using several common criteria. First, the correlation matrix was inspected to determine if each observation variable shared a correlation of .3 or greater with at least one other variable. It was discovered that 6 of the 30 variables did not meet this criterion. These were, from the Course Ideas category: Facts/Definitions, Procedures/Instructions, Strategies, Behavior Expectations, Housekeeping, and from the Instructor Behavior category: Listen/Watching. These items were removed from the analysis. Furthermore, the only items remaining in the Course Ideas category were Big Ideas and Explicit Connections. Given that Big Ideas is most commonly coded throughout an entire classroom period during GlobalEd 2 implementation (with the exception of opening and closing activities), the code was deemed redundant and removed from the analysis. Furthermore, since the Explicit Connections code is an item which was intended to co-occur with Big Ideas and one other item from the Course Ideas category (i.e. Facts/Definitions), but did not appear to co-occur in this manner, as evidenced by the lack of meaningful correlations, a decision was made to eliminate the Course Ideas category from the analysis entirely. This decision was further bolstered by the fact that the focus of the study was on the examination of teacher/student behavior or more specifically, the manner in which teachers guided their students as they implemented the GlobalEd 2 curriculum.

With the aforementioned variables removed, the PCA was rerun. The correlation matrix showed that all the variables had at least one correlation coefficient greater than .3, suggesting reasonable factorability. The overall Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .771 with individual KMO measures exceeding the recommended value of .6 (Tabachnik & Fidell, 2007). Bartlett's test of sphericity was significant ($\chi 2$ (231) = 4666.61, $p < .0005$) indicating the data to be suitable for structure detection. Lastly, the communalities, which represent the variance accounted for by the components for each variable, were above .45 for all but one variable: Leading Discussion (.37). Given the results of these measures, PCA was deemed a suitable analysis.

The analysis extracted six components with eigenvalues greater than one, explaining 21.9%, 15.6%, 8.3%, 7.7%, 5.8%, and 5.0% of the total variance, respectively. Since the sixth component only accounted for 5% of the total variance, the minimum criteria for retention, it was considered questionable. In addition, the six-component solution resulted in complex structure and did not meet the interpretability criterion. Therefore, PCA was repeated with a five component limit.

With the five-component solution, most communalities obtained values of .4 or above, except for Leading Discussion (.36) and Discussion (.34). However, since these variables were considered valuable in contextualizing classroom activities, they were retained for analysis. The five-component solution explained 59% of the variance and represented a simpler structure. In order to interpret and define each component, each variable's contribution or loading was examined. Variable loadings and communalities are shown in Table 2. The table lists the variables in descending order to ease interpretability. Component 1 involves students working collaboratively in small groups on research or project work while the tutor circulates the classroom and talks with students. The teacher/student exchanges here can be considered surface-level (e.g. reminding students to stay on task, .26 loading), since they do not co-occur with qualifying codes, such as coaching or modeling. Component 2 exemplifies instruction instances driven by students' needs and questions, during which the tutor offers feedback related to students' work and/or their process. In contrast to the interactions represented by component 1, the feedback provided here, is more substantial, since it is specifically intended to address students' needs. Component 3 characterizes occasions where the tutor facilitates student learning through coaching and modeling based on the knowledge and reasoning students reveal as they engage in various activities. Component 4 solely represents instances during which students work independently. This excludes small group work and any tutor involvement. Component 5 showcases students engaging in reflection and/or self/peer assessment. This usually occurs as part of a tutor initiated discussion.

Scores for the five components were saved for each teacher's observation. The observations were then averaged across each teacher and the mean component scores were utilized in a subsequent cluster analysis.

Table 2

Component Loadings and Communalities (h_2) for Principal Components Extraction with 22 Observation Variables

Observation Variable	Component loading					h_2
	1	2	3	4	5	
Component 1: Students Work on Project as Tutor Circulates						
Talking to individuals/groups	**.74**	.00	.00	.00	.00	.63
Research or project work	**.71**	.00	.00	.00	.00	.75
Grouping - Small group/Pairs	**.67**	.00	.00	-.32	.00	.78
Students help each other	**.61**	.00	.00	.00	.00	.56
Direct instruction	**-.62**	.27	.00	.00	.00	.45
Question/Response	**-.63**	.48	.00	.00	.00	.60
Listening/note-taking	**-.76**	.00	.32	.00	.00	.57
Grouping - Whole Class	**-.91**	.00	.00	.00	.00	.77
Component 2: Question/Response Session Based on Student's Needs						
Instructor responds to students' needs/Students questions or needs drive activity	.00	**.76**	.00	.00	.00	.55
Instructor feedback about products/process	.26	**.74**	.00	.00	.00	.63
Students share their ideas / conjectures	.00	**.66**	.00	.00	.27	.67
Students react to each other's ideas	.00	**.43**	.00	.00	.26	.69
Component 3: Tutor Coaches Students Based on Their Knowledge and Reasoning						
Activities make students' knowledge visible	.00	.00	**.95**	.00	.00	.79
Activities make students' reasoning visible	.00	.00	**.84**	.00	.00	.75
Coaching / Modeling	.00	.33	**.43**	.00	-.35	.58
Student discussion	.00	.00	**.38**	.00	.28	.68
Component 4: Student Independent Work						
Grouping - Individual	.00	.00	.00	**.93**	.00	.82
Independent work	.00	.00	.00	**.93**	.00	.82
Component 5: Reflection Through Class Discussion						
Reflecting on own knowledge/skills and/or group experience	.00	.00	.00	.00	**.74**	.62
Student self and/or peer assessment	.00	.00	.00	.00	**.70**	.49
Presenting ideas / findings	.00	.00	.00	.00	**.50**	.58
Teacher leading discussion	-.33	.00	.00	.00	**.40**	.37

Note. The extraction method was principal components with an oblique (Promax with Kaiser Normalization) rotation. Predominant component loadings above .30 are in bold.

Cluster analysis. Following the PCA, a cluster analysis was utilized to identify common patterns of instruction during GlobalEd 2 implementation. Cluster analysis is an exploratory statistical technique that aims to identify groups within data (e.g. people, cases) and classify them according to their shared characteristics (Aldenderfer & Blashfield, 1984). Cluster analysis differs from other data reduction techniques such as factor analysis or principal components analysis in that these procedures reduce the number of variables into factors/components, whereas cluster analysis groups observations or cases into profiles or taxonomies (Crowther & Lauesen, 2017). The analysis has been widely used in education research to assist with deriving profiles from classroom behaviors and other learning environment characteristics (LoCasale-Crouch et al., 2007; Wilson, Pianta, & Stuhlman, 2007).

There are various methods of clustering, but two approaches considered most common are partitional and hierarchical clustering. Partitional clustering, such as the K-means method, involves the partitioning of data points into non-overlapping, mutually exclusive groups or clusters. In contrast, subgroups of data-points nested within larger groups, forming a tree-like structure, can be obtained through hierarchical cluster analysis, such as Ward's (Tan, Steinbach, & Kumar, 2006).

K-means analysis produces clusters of greatest achievable distinction based on a researcher-specified number of clusters (Burns & Burns, 2008). Once a specific number of clusters is requested, the procedure begins with the selection of initial cluster seeds, which are guesstimates of the preliminary cluster centroids or means (Hair & Black, 2000). At this stage, all cases within a particular distance from the cluster centers, which is most commonly measured as Euclidean distance, are assigned to their initial clusters.

Subsequently, the cluster centroids are updated based on all of the cases in each cluster and case reassignment takes place. As this cycle continues, the procedure aims to minimize the sum of squared error (SSE), which is the Euclidean distance of each data point to the closest centroid. The smaller the squared error, the better the cluster centers represent the data within each cluster. This iterative process persists until there is no substantial change in the cluster centers (Tan, Steinbach, & Kumar, 2006).

Although Ward's clustering method is designed to uncover a hierarchical data structure, the goal of the procedure is like that of the K-means method, to minimize the sum of squared errors or distances among the data points and cluster centers. However, this method is not iterative in the way the K-means method is, thus although the Ward's algorithm can determine the optimal initial cluster seeds, it is unable to make optimized decisions regarding the total sum of squared errors as clusters merge at each level of the hierarchy. This means that cases that are grouped into particular clusters at the outset of the analysis, cannot change their classification even though an alternative cluster placement could have provided a better fit (Tan, Steinbach, & Kumar, 2006).

For this analysis, K-means clustering was employed as the method for identifying the instructional profiles during GlobalEd 2 implementation, however, Ward's clustering was utilized at the outset of the analysis in order to help identify the appropriate number of clusters or profiles present in the dataset, which is a common practice (Burns & Burns, 2008). The Ward's method is helpful in this regard, since it provides a variety of similarity and distance measures that can be examined to make this determination. For instance, the dendrogram, a tree-like graph, provides a visual representation of the data structure, which can aid in choosing the number of viable clusters. In addition, an evaluation of the agglomeration schedule allows for the identification of significant jumps in distance measures between clustering stages, which signify the most appropriate stopping points for the procedure (Burns & Burns, 2008).

After an assessment of the agglomeration schedule, visual inspection of the dendrogram, and an assessment of the interpretability of Ward's proposed results, a two cluster solution was deemed most appropriate. Subsequently, a K-means cluster analysis was run for a two cluster solution. The final cluster centers or the standardized means for each implementation profile cluster are displayed in Table 3. Complete descriptive statistics for the two clusters are included in Table 4. In addition, cluster stability was assessed via the split-sample method (Clatworthy, Buick, Hankins, Weinman, & Horne, 2005). Cluster stability was confirmed since both data subsets represented cluster structure similar to that of the original clusters, see Appendix H. Characterization of the two clusters was performed by inspecting each cluster's standardized means and is presented next.

Table 3

Means and Standard Deviations for Each Implementation Cluster

Principal Components (PC)	Cluster 1 PBL Learning *n* = 19		Cluster 2 Independent Learning *n* = 34	
	M	*SD*	*M*	*SD*
PC1 - Research/Project Work as Tutor Circulates	0.11	0.51	-0.08	0.54
PC2 - Q/R Based on Student's Needs	0.36	0.56	-0.21	0.58
PC3 - Tutor Coaches Students	0.69	0.37	-0.37	0.45
PC4 - Student Independent Work	-0.33	0.32	0.19	0.48
PC5 - Reflection Through Class Discussion	0.30	0.69	-0.18	0.28

***Note*.** QR = question/response session

Instruction during GlobalEd 2 implementation demonstrated in cluster 1 (*n* = 19) is defined by above average mean scores for component 1 - Research/Project Work as Tutor Circulates, component 2 - Question/Response Based on Student's Needs, component 3 - Tutor Coaches Students, and component 5 - Reflection Through Class Discussion. The composition of this cluster theoretically exemplifies a PBL classroom, with the instructor taking on a role of a coach, helping to facilitate, rather than direct student learning. Special attention is given to examine students' understanding and pausing to provide clarification and guidance. It illustrates students working collaboratively throughout the simulation and partaking in discussions where they evaluate their understanding of the content and assess their progress. Based on this characterization, this cluster is labeled the "PBL Learning" cluster.

Instruction during GlobalEd 2 implementation demonstrated in cluster 2 (*n* = 34) is defined by an above average mean score for component 4 - Student Independent Work and below average mean scores on the other four components. To add, results of component 3 – Tutor Coaches Students, shows the greatest discrepancy between the two implementation profiles. Thus, although students experienced instructional elements encompassed by all components to some extent (see Table 4 for range measures for each component**)**, the composition of this cluster is dominated by the fact that a greater amount of time during GlobalEd 2 was spent by students working without the support and guidance of their tutor and often, tackling the assignment independently, rather than within the collaborative structure of the PBL tutorial group. Based on this characterization, this cluster is labeled the "Independent Learning" cluster.

Table 4

Descriptive Statistics per Cluster

Principal Components (PC)	PBL Learning Cluster *n* = 19						Independent Learning Cluster *n* = 34					
	Mean	*SD*	*95% CI*		*Min*	*Max*	*Mean*	*SD*	*95% CI*		*Min*	*Max*
			Lower	*Upper*					*Lower*	*Upper*		
PC1 Research/Project Work as Tutor Circulates	0.11	0.51	-.14	.35	-.90	.97	-0.08	0.54	-.27	.11	-1.14	1.09
PC2 Question/Response Based on Student's Needs	0.36	0.56	.09	.63	-.75	1.76	-0.21	0.58	-.41	-.01	-1.25	.74
PC3 Tutor Coaches Students	0.69	0.37	.51	.86	.03	1.36	-0.37	0.45	-.53	-.22	-1.21	.70
PC4 Student Independent Work	-0.33	0.32	-.49	-.18	-.78	.44	0.19	0.48	.02	.36	-.55	1.32
PC5 Reflection Through Class Discussion	0.30	0.69	-.03	.63	-.42	1.91	-0.18	0.28	-.28	-.09	-.68	.47

To understand the composition of the implementation profile groups from a demographic perspective, Tables 5 and 6 are presented delineating teacher and student demographics per group. With regards to teacher demographics, gender wise, the PBL Learning group was relatively equally represented by both females and males. The Independent Learning group was more predominantly comprised of female teachers. The Independent Learning teachers also served urban districts 17% more than did their counterparts. There was a slight difference in teacher education with 12% more of the Independent Learning teachers holding higher education degrees. In addition, although the Independent Learning group was more heavily comprised of teachers that had 10 or more years of teaching experience, 85.3% of them (in comparison to 68.4% of the PBL Learning teachers), were implementing the PBL program for the first time.

Table 5

Teacher Demographics per Implementation Profile

		PBL Learning *n* = 19		Independent Learning *n* = 34		Total *n* = 53	
		n	%	*n*	%	*n*	%
Gender	Female	9	47.4	24	70.6	33	62.3
	Male	10	52.6	10	29.4	20	37.7
Stratum	Urban	8	42.1	20	58.8	28	47.2
	Suburban	11	57.9	14	41.2	25	52.8
Education	Bachelor's	5	27.8	5	16.1	10	20.4
	Master's	13	72.2	26	83.9	39	79.6
Years Taught	Less than 3	2	11.1	1	3.2	3	6.1
	3 to 9	10	55.6	15	48.4	25	51.0
	10 to 20	4	22.2	10	32.3	14	28.6
	Over 20	2	11.1	5	16.1	7	14.3
Previous GlobalEd 2 Participation	Yes	6	31.6	5	14.7	11	20.8
	No	13	68.4	29	85.3	42	79.2

With regard to student demographics, student gender and grade level were comparable across implementation profiles. There were slight differences between groups in terms of locale and ethnicity, with a slightly greater preponderance of students from urban settings, as well as students of Hispanic/Latino background comprising the Independent Learning group. More importantly however, students of the Independent Learning group were more economically disadvantaged by 14.2% than students in the PBL Learning group.

Table 6

Student Demographics per Implementation Profile

		PBL Learning *n* = 357		Independent Learning *n* = 641		Total *n* =998	
		n	%	*n*	%	*n*	%
Gender	Female	178	50.9	341	54.6	519	53.3
	Male	172	49.1	283	45.4	455	46.7
Grade	7th	202	56.6	323	50.6	525	52.8
	8th	155	43.4	315	49.4	470	47.2
Stratum	Urban	169	47.3	366	57.1	535	53.6
	Suburban	188	52.7	275	42.9	463	46.4
Ethnicity	White	167	47.9	261	41.2	428	43.6
	Black	55	15.8	73	11.5	128	13.0
	Hispanic/Latino	76	21.8	207	32.7	283	28.8
	Other	51	14.5	92	14.6	143	14.6
Poverty	High	126	38.7	228	35.6	354	36.6
	Mid-high	0	0	111	17.3	111	11.5
	Mid-low	123	37.7	126	19.7	249	25.7
	Low	77	23.6	176	27.5	253	26.2

Note. High level of poverty referred to schools reporting 75% or above of reduced or free lunch. Mid-high referred to schools with 51-75% of reduced or free lunch, mid-low with 25-50%, and low, with 25% or below reduced or free lunch.

Analysis Addressing Research Question 2

RQ2. After controlling for students' pre-writing assessment scores, does implementation type have an effect on students' post-writing assessment outcomes?

In order to understand if teacher implementation practices impacted student writing assessment outcomes, analysis of covariance (ANCOVA) was employed. Prior to conducting the analysis however, student data, parsed into groups representing the different implementation profiles, was examined for accuracy and fit.

Data screening and preliminary analyses. For the PBL Learning group, data were missing for 22 students (6.2%) on the pre-writing assessment and 33 students (9.2%) on the post-writing assessment. For the Independent Learning group, data were missing for 28 students (4.4%) on the pre-writing assessment and 52 students (8.1%) on the post-writing assessment. A chi-square test of independence showed no association between group (implementation type) and missing data on the pre-assessment, $\chi^2(1) = 1.55$, $p = 0.21$, or post-assessment, $\chi^2(1) = .28$, $p = 0.60$, indicating both groups were as likely to possess missing values.

Meeting the assumption of normality for an ANCOVA involves inspecting whether the standardized residuals are normally distributed. The standardized residuals for the PBL Learning group possessed a minor skew (skewness = .12, SE = .14) and a minor kurtosis (kurtosis = .11, SE = .27). The distribution was considered normally distributed according to results of the Shapiro-Wilk's test ($p > .05$). Visual inspection of a histogram confirmed the bell-shaped distribution of the standardized residuals for this group. The standardized residuals for the Independent Learning group possessed a more pronounced skew (skewness = .37, SE = .10) and kurtosis (kurtosis = .39, SE = .20). The Shapiro-Wilk's test was found to be significant ($p = .002$), indicating that the standardized residuals did not follow a normal distribution. Inspection of a histogram indicated that there may be outlying cases present.

Grouped data were inspected for outliers by identifying cases with standardized residuals greater than ±3 standard deviations. No outliers were detected in the PBL

Learning group data. In the Independent Learning group data, four cases exceeded the ±3 standard deviations rule. The outlying cases were individually inspected. Each case represented legitimate, albeit higher than average scores. Several data transformations of the dependent variable were attempted, but resulted in poorer distributions, hence the outlying cases were retained.

The assumption of linearity, which supposes that the covariate (pre-assessment scores) should be linearly related to the dependent variable (post-assessment scores) at each level of the independent variable (implementation type), was tested by visually inspecting a scatterplot. A linear relationship was found between pre- and post-assessment scores for each implementation group, hence the assumption was met. Furthermore, the assumption of homogeneity of regression slopes, which presumes that no interaction exists between the covariate and the independent variable was also met, given that the interaction term was found to not be statistically significant, F (1, 908) = .035, p = .852.

The assumptions of homoscedasticity of error variances within each group, as well as homogeneity of error variances between groups were subsequently evaluated. Through the visual inspection of scatter plots displaying the standardized residuals plotted against the predicted values for each implementation group, homoscedasticity appeared to have been met. Levene's test of equality of variances was performed to assess if variance of the residuals is equal for both groups of the independent variable. Levene's test was not significant (p = .132), indicating that the assumption of homogeneity of error variances was met. Moreover, given Levene's test's insensitivity to departures from normality and the concern over unequal cell sizes of the implementation groups (PBL Learning Group, $n = 324$; Independent Learning Group, $n = 588$), Hartely's F_{max} test was performed (Tabachinck & Fidell, 2007). Homogeneity of variance was confirmed with the ratio of pre- and post-assessment variances between groups resulting in values close to 1 (PBL Learning Group, $F_{max} = 1.02$; Independent Learning Group, $F_{max} = 1.15$). In addition, it should be noted that although unequal cell sizes are a concern for ANCOVA, since they can influence statistical power and increase the chance of making a Type I error, SPSS software adjusts for this difference when conducting the analysis (Tabachinck & Fidell, 2007).

Analysis of covariance. To address the second research question, a One-Way ANCOVA was performed. The procedure initially conducts a regression of the covariate on the dependent variable, after which, the unexplained variance (residuals) is subject to an ANOVA. The aim for the One-Way ANCOVA is to test whether the independent variable still influences the dependent variable after the influence of the covariate has been removed (Tabachinck & Fidell, 2007). In the context of this study, type of implementation (levels of the independent variable) was entered as the fixed factor, with students' pre-writing assessment scores as the covariate, and students' post-writing assessment scores as the dependent variable. After adjustment for pre-writing assessment scores, there was a statistically significant difference in post-writing assessment scores between the implementation groups, $F_{(1, 909)} = 32.849$, $p < .004$. Post-writing assessment scores were statistically significantly greater for the PBL Learning group ($M = 7.71$, $SE = .11$) compared to the Independent Learning Group ($M = 7.31$, $SE = .08$), a mean difference of 0.40, 95% CI [0.123, 0.670], $p < .004$. The adjusted and unadjusted means and standard deviations for the post-writing assessment scores can be found in Table 7.

Table 7

Unadjusted and Adjusted Means and Standard Deviations for Post-Writing Assessment Scores After Adjusting for Pre-Writing Assessment Scores

Implementation type		Unadjusted		Adjusted	
	n	*M*	*SD*	*M*	*SD*
PBL Learning Group	324	7.73	2.29	7.71	.11
Independent Learning Group	588	7.30	2.14	7.31	.08

Analysis Addressing Research Question 3

RQ3. What possible factors influenced the manner in which GlobalEd 2 was enacted?

In order to gain greater insight as to the potential factors that might have influenced implementation of the PBL curricula, content analysis was performed. Content analysis is a method for the examination of qualitative data, which includes any form of verbal, visual, or written communication (Downe-Wambolt, 1992), such as interviews, articles, imagery, and alike (Hsieh & Shannon, 2005). Content analysis can be utilized as a quantitative method for the, “objective, systematic, and quantitative description of the manifest content of communication” (Berelson, 1952, p. 18). However, it can also be employed as a qualitative method when the goal of the inquiry is to gain a more holistic understanding of the phenomenon being studied (Cho & Lee, 2014). In such case, it can be defined as, “a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005, p. 1278). The analysis is also often described as either attending to the manifest (surface level) content or to the latent meaning (interpretive level) of content found in the data (Downe-Wambolt, 1992). Moreover, patterns in the data can be identified through inductive or deductive approaches (Bengtsson, 2016). The inductive method involves creating codes or themes that emerge from the data itself, whereas the deductive method begins with predetermined codes or categories that stem from established theory or relevant literature (Cho & Lee, 2014). Since this study is explorative in nature, an inductive approach to content analysis was employed.

There are different strategies to how content analysis may be performed, but most practices involve the following four stages throughout the analysis process: decontextualization, recontextualization, categorization, and compilation (Bengtsson, 2016). The order of the stages may vary across approaches, but the process overall is meant to be iterative in nature and requires the researcher to continually revisit the stages and reassess the coding scheme as she/he becomes more familiar with the data or if additional data becomes available (Bengtsson, 2016). During the decontextualization stage, the researcher's goal is to first become well acquainted with the data in its entirety. In the case of interview data, this would require a complete read through the interview transcripts. Subsequently, the researcher engages in open coding by identifying and coding meaning units, which are sections of text that represent concepts viewed as pertinent to answering the research question (Berg, 2001). It is advisable to compose a list of codes and their definitions, "to minimize a cognitive change during the process of analysis and in order to secure reliability" (Bengtsson, 2016, p. 12). When an inductive approach to content analysis is adopted, codes may change as the analysis progresses, which makes keeping a code book essential. Once the preliminary identification and coding of meaning units is complete, the researcher has to examine the remaining text to assess if any pertinent information could still be extracted. This process of recontextualization allows the researcher to decide if the remaining text should be included in the analysis or excluded from it and make certain that no data relevant to answering the research question was omitted (Bengtsson, 2016).

Next, the process of categorization can begin, which involves combining coded sections of text on the basis of shared content. Categories are intended to be mutually exclusive and internally homogeneous (Bengtsson, 2016). The establishment of categories is followed by the creation of themes, which more holistically explain the underlying meanings within and/or across categories (Cho & Lee, 2014). Finally, the analysis and write-up of results, the compilation stage, commences.

Throughout the process, the researcher strives to view the data from a neutral perspective and intends to remain objective (Bengtsson, 2016). If taking a manifest approach to the data analysis, the investigator's aim is to compile results based on the categories formed and to remain close to the original words and concepts derived from the text on which the categories were based. In the latent approach, the investigator constructs his/her explanation of the phenomenon being studied based on the underlying meanings represented through the themes.

For the findings of qualitative analysis to be considered trustworthy and meaningful, many researchers follow the criteria of credibility, transferability, dependability, and confirmability set forth by Lincoln and Guba (1985). Credibility, analogous to validity, refers to the legitimacy of the analysis and its findings. Examining credibility helps to determine whether or not the results accurately reflect what participants were attempting to convey (Anney, 2014; Lincoln & Guba, 1985). Transferability, comparable to generalizability, requires the researcher to provide rich descriptions, so that others may be able to potentially transfer or apply the findings of the research to their own work (Lincoln & Guba, 1985; Nowell, Norris, White, & Moules, 2017). Dependability represents the stability of the work (Bengtsson, 2016) and is achieved through transparency of the research process and its logic (Nowell, Norris, White, & Moules, 2017). Confirmability refers to the extent to which the findings could be verified (Anney, 2014), thus ultimately, when credibility, transferability, and dependability have been attained (Guba & Lincoln (1989) as cited in Nowell, Norris, White, & Moules, 2017).

For this investigation, in order to gain greater insight as to the potential factors that might have influenced how teachers implemented the GlobalEd 2 simulation, content analysis was performed on 53 teacher post-simulation interviews. Although the interviews were transcribed in their entirety verbatim, five interview questions became the focus of the analysis. These questions were seen as most applicable to answering the research question based on previously proposed factors in the literature shown to influence implementation. The chosen questions sought to understand the instructors' teaching philosophies, how prepared they felt to implement the simulation after the GlobalEd 2 professional development, what they did to prepare themselves before the simulation commenced, what challenges they faced during enactment, and the modifications they made and resources they used throughout.

During the decontextualization process, responses to questions chosen as unit of analysis were read thoroughly by the researcher for all 53 participants in order to gain an overall understanding of the data. Next, a secondary pass through the data was conducted to identify meaning units across responses. During this process, open coding was initiated in which a code was assigned to each meaning unit, reflective of its content. This process was recursive in that meaning units and codes were revisited and modified as the researcher moved through the data. A code list and memos were kept to track the changes. Subsequently, during the recontextualization phase, the text was re-read alongside the meaning units and codes in order to determine if any remaining text contained content relevant to answering the research question, but was initially omitted. This proved not to be the case. Next, coded responses were categorized according to the domains they represented, largely reflective of the questions they derived from. Finally, overarching themes were composed grouping related, coded concepts. The process involved moving concepts between themes and attuning themes to best reflect the data contained within, before the analysis was finalized. Examples of coded interview excerpts can be found in Table 8. In order to assure credibility or validity of the analysis, a sample of the coded interview data was reviewed by an outside researcher in the field, impartial to the study, and agreement was reached on the final version of the coding scheme. The complete coding scheme can be found in Appendix I. Finally, relationships between coded segments across both implementation profiles were examined.

Table 8

Coded Excerpts Derived from Transcribed Interviews with Teachers Implementing the GlobalEd 2 Curriculum

Meaning unit	Code	Category	Theme
"I really subscribe to the model of seeing the teacher position as more of a facilitator. I really like my students to think for themselves by generating their own questions and exploring and researching and then ultimately coming to a consensus with peers by using discussion skills to debate topics. I've never been one to convey my own opinion. I really like the kids to discover on their own."	Facilitating learning Inquiry/discovery learning Student collaboration Inquiry/discovery learning	Philosophy	Modern conception of learning
"So looking back at the end of the training in the summer, I thought I was prepared, but then when I started the program, I feel like I wasn't as prepared as I thought I was."	Prepared/Shocked	GlobalEd 2 Preparation (Professional Development)	False feelings of preparedness
"I went through the teacher's curriculum quite a bit. I, like, tagged the pages in the lessons I liked and went through the student workbook and also, like, tagged all the worksheets that I thought would be relevant. So that, that was helpful. I mean it was definitely super helpful to have all those teacher resources."	Reviewed GlobalEd 2 curriculum Reviewed GlobalEd 2 student workbook	Teacher's Own Preparation	Reviewed materials in preparation for implementation
"Actually I pretty much, the materials that I used out of the curriculum guide or the student workbook, I didn't feel I needed to modify. I used a lot of them as they were printed and a lot of them were quite helpful, obviously the IPads and the keyboards."	Did not modify	Modifications	GlobalEd 2 resources not modified
"This year we had a lot of mandates as far testing. So there was a social studies class that would be, a social studies and science class that would be out every Monday because of testing or due to reading and math interventions. So like on Monday and, on Monday science and social studies did not have it because of reading and math interventions. So that made things a little bit more challenging in times of fitting GlobalEd in. So I had a lot more time last year than this year. And then because we were testing every, like every five weeks, that also caused an interruption."	Limited time due to testing or other interventions	Challenges	Lack of time as a challenge to implementation

The content analysis revealed some similarity across implementation groups; however, several key differences also emerged between them. These differences could help inform why implementation practices varied. The comparable, as well as the divergent findings will be discussed in the following section broken out into the aforementioned categories: teaching philosophy, GlobalEd 2 preparation, teachers' own preparation, challenges faced, and curricular modifications made. In order to more precisely illustrate teachers' responses across implementation profiles, percent occurrence of major themes within each category has been included. Percent occurrence of responses indicates the proportion of teachers that expressed a particular statement, rather than the proportion of the number of times a statement was made. Tables listing all percent occurrences for the major themes within a category are listed at the end of each section.

Philosophy. Several themes emerged from teachers' explanations of their teaching philosophies. Majority of teachers across both implementation profiles reported to support a contemporary view of learning (67% PBL Grp, 70% Indep. Grp). This encompassed a learning environment that was student-centered in nature, where student inquiry or discovery were promoted as critical aspects of the learning process. Interactive, hands-on learning was also stressed as being key to some teachers' philosophies and viewed as more beneficial than more passive forms of learning. Several teachers mentioned that in fact, they saw their pedagogical style reflective of project or problem-based learning, where student collaboration was valued and where the teacher viewed her/himself as a facilitator, scaffolding student learning. Some of these characteristics are reflected in the following example.

> I really subscribe to the model of seeing the teacher position as more of a facilitator. I really like my students to think for themselves by generating their own questions and exploring and researching and then ultimately coming to a consensus with peers by using discussion skills to debate topics. I've never been one to convey my own opinion. I really like the kids to discover on their own

In addition, several teachers emphasized that for them, the importance of keeping students engaged and focused throughout the learning process was central. Teachers identified the use of guided questions as a strategy to help students remain centered as they explored new material. They highlighted the use of themes interwoven across activities or units to aid students in making associations among concepts.

Some teachers, a comparable number across both groups, subscribed to a largely traditional pedagogical view (32% PBL Grp, 35% Indep. Grp), which most described as more teacher-centered and involving a 'gradual release' of power and focus from teacher to student over the course of a class. This most often entailed the teacher providing students with content knowledge at the outset of class, conducting a joint activity, and finally, having students engage with the content individually or collaboratively with peers.

> We'll do a little bit of reading, maybe we watch a PowerPoint, so there's a little bit of note taking, but then there's something where they're doing. There's a lot of modeling that I do and so I suppose philosophy is a gradual release. That seems to be the buzz word lately. I do, we do, you do, and that works really well.

Another theme that emerged within the philosophy category was one that emphasized the importance of creating a space where students felt cared for and valued. An environment that fostered the belief that all students could learn and do well if they were supported. And a classroom in which teachers put forth effort to attend to students' needs. Here for example, one teacher emphasized the significance of the teacher/student relationship in helping students learn.

> Do whatever it takes to meet the kids' needs and my goal has always been to just love them, because if you don't have a relationship, then nothing is going to happen anyway, but I do try more and more to adjust my teaching style to what they need…

This was a belief that set the two implementation groups apart to a great extent. Close to half (47%) of the teachers in the PBL Learning Group named this as central to their philosophy of teaching, whereas less than a third (29%) of the Independent Learning teachers shared this view.

The last theme that emerged within this category materialized as discipline-based. Since GlobalEd 2 was to be enacted in social studies classrooms, the teachers implementing it were primarily social studies and history teachers. And what surfaced as a significant part of the teachers' philosophy was the importance of students having an opportunity to connect their learning not only to self, but to the larger, global community. In one teacher's words, "I would say for me, it [teaching philosophy] is social studies specific and creating students who are aware and understand the world around them and that are able to use their own experiences to relate to those situations." Fostering empathy for others and being able to take a global perspective were also central to this view. In addition, several teachers stressed the importance of integrating current events and real world issues into their teaching. One teacher expressed that it was important to him to, "Connect to today, make relevant, connect to real world problems, global perspective, connect the material to their daily lives and to the global world as a whole." This particular belief was expressed predominantly by the Independent Learning teachers. Approximately a third of the teachers from this group (32% Indep. Grp, 11% PBL Grp) held this conviction, and for more than half of them (55%), this was the only pedagogical stance they conveyed.

Table 9

Content Analysis Findings for Pedagogical Philosophy Represented by Percent Occurrence of Teachers' Responses

	PBL Implementation *n* = 19	Independent Learning *n* = 34
Philosophy		
Contemporary Pedagogical Views	67%	70%
Traditional Pedagogical Views	32%	35%
Supportive Learning Environment	47%	29%
Discipline Specific Focus	11%	32%

Globaled 2 Preparation. When asked how comfortable and prepared teachers felt to implement the GlobalEd 2 simulation in their classrooms, teachers usually declared their level of preparation and then, most expounded on why the case was such. Slightly more than half of teachers across both implementation profiles expressed feeling fairly prepared to implement the simulation (63% PBL, 59% Indep. Grp). A comparable amount of teachers from each group (21% PBL Grp, 18% Indep. Grp) specified that they did not feel ready at all. In one teacher's words, "I didn't feel prepared at all. I felt like I just- I have an experience, but right now, when I look back, I wasn't prepared." For some, this sentiment was expressed in terms of not feeling comfortable about implementation in general, and for others, it was specific to the science content or the problem-based learning method itself.

> For me, in terms of PBL, I think I could have used a bit more training. I thought that the problem was going to be put in front of me, like 'there's a water scarcity issue' or 'a water contamination problem going on in your country right now,' but really we had to look for the problem…I think that the science part of it could have been more scaffold for me as a teacher. You figure out what the problem is and there's a lot of creating going on by the teacher.

In addition, other teachers, an equal number across both groups (21% PBL Grp, 21% Indep. Grp), explained that they actually thought they were ready after the summer professional development training, but once the simulation commenced, they realized they were not. One of the teachers explained how this falsified sense of readiness became evident only after she had the opportunity to see her students engage in the simulation,

> I felt comfortable after the summer training, but I think that was, because I hadn't actually implemented it yet. The feeling switched after I started implementing stuff…I think that's because I participated in it, so everything came from my perspective and I didn't put myself enough into my student's perspective to see how difficult it could be for them.

With regard to additional explanations teachers offered for feeling uneasy about implementing GlobalEd 2, two themes emerged and were expressed solely by teachers implementing GlobalEd 2 for the first time. New GlobalEd 2 teachers across both implementation groups, shared the fact that they felt overwhelmed and anxious as the start of the simulation was nearing (26% PBL Grp, 32% Indep. Grp). This was often attributed to the unknown of what was to come, as the following teacher explained, "This was the first year I implemented it, so I was kind of apprehensive at first, because I didn't know what to expect." Although several teachers found the interactive part of the training beneficial, which involved a pseudo GlobalEd 2 simulation and a live discussion; others conveyed that they wished they would have had an opportunity to see GlobalEd 2 in action, to at least, "…see one lesson being implemented." Teachers also disclosed that they were unsure of timing and how they would manage implementing GlobalEd 2 along with their regular curriculum. One teacher explained,

> With the content and with the ideas, I was very comfortable, but managing GE2 and the curriculum that I'm supposed to teach, it's funny, at the end of it I tried to reflect on how I was doing with everything and it was hard, but there's so many

> things I would do differently if I did it again. Because you figure it out. It takes you that first month of being in it to figure it out.

Several teachers also shared that initially, they were concerned with and intimidated by the technological aspect of the simulation, but overcame these trepidations with additional assistance from the GlobalEd 2 staff before the project began.

In addition to feeling anxious, teachers often mentioned feeling overwhelmed by the level and amount of GlobalEd 2 resources available to them (32% PBL Grp; 24% Indep. Grp). Although the GlobalEd 2 research team made great effort to provide teachers with leveled resources covering various content areas related to the simulation topic, approximately a third of the teachers were still concerned that the GlobalEd 2 materials were going to be too difficult for their students. Here a teacher articulates her concerns regarding the complexity of the materials, as well as the amount of additional work involved in order to make adjustments to make the resources more suitable for her students,

> I mean, I thought after the summer, it seemed pretty straight forward. But when I got all the materials and I saw everything, I was like, holy [expletive]. Like, I needed to differentiate and modify so many things on there that it was so much work to get the ball rolling with it. I mean the language, the language that is written on there is high school level.

The sheer number of resources, although appreciated by most, was also found to be overwhelming for many just starting out with GlobalEd 2. From the commentary, it could be gathered that for some of the teachers there was too much to sift through and choose from. It appeared that this level of autonomy could be paralyzing, as this teacher explained,

> I didn’t get a general flow, there’s a ton of resources, but I didn’t. For me it was very hard to comprehend. Ok, I’m going to pull this from here and use it and I just had a hard time putting it together.

Since GlobalEd 2 is not a scripted curriculum, deciding on what would be most valuable to use in the timeframe teachers had, became perplexing for some. “There seemed to be so much for us to use and made us wonder what we should use and what we should leave out,” commented a teacher. Feeling inundated appeared to have a negative effect on some teachers, potentially driving them to turn away from materials prepared for them in search of their own.

> I remember being nervous and I remember in the beginning using more of my own resources that I was coming up with instead of embracing the program…there was so many e-mails from you guys, and so many links and things that I found it daunting sometimes, so I would just find something really quick on my own.

There was some positive feedback with regard to the ongoing professional development teachers received from the GlobalEd 2 staff, however. The GlobalEd 2 bulletin for example, was a weekly email teachers received to help them stay on track with the flow of the simulation. It included reminders of upcoming events (e.g. deadlines for posting opening statements, synchronous conference dates/times), provided suggestions of GlobalEd 2 lessons, which could be employed during a given week, as well as links to additional resources (e.g. articles, podcasts, videos). Here a teacher remarks how she found the GlobalEd 2 bulletin to be anchoring for her,

> There was a panic there, but what really helped was the weekly bulletins. I think that really got rid of a lot of the fears that- okay, here's the curriculum, we're not just going to let you alone, sink or swim kind of thing.

Several teachers also remarked that they found comfort and support by being able to lean on other GlobalEd 2 teachers in their school or content expert teachers (i.e. science) not involved in the project, but willing to offer additional assistance.

Table 10

Content Analysis Findings for GlobalEd 2 Preparation Represented by Percent Occurrence of Teachers' Responses

	PBL Implementation *n* = 19	Independent Learning *n* = 34
GlobalEd 2 Preparation		
Fairly Prepared	63%	59%
Not Prepared	21%	18%
Falsely Ready	21%	21%
First-year Anxieties/Uncertainties	26%	32%
Overwhelmed by Difficulty and Amount of Curricular Resources	32%	24%
Felt Supported	11%	9%
PD Feedback	26%	29%

Teachers' Own Preparation. With regard to what teachers did to prepare themselves before the start of the GlobalEd 2 simulation, 21% of teachers from each group reported to not have engaged in any preparation beyond the summer professional development. Those that did attempt to ready themselves a step further, allocated most of their effort to reviewing materials relevant to the simulation content (74% PBL Grp, 79% Indep. Grp). Most frequently, teachers reported conducting online searches for articles discussing water scarcity issues related to their assigned country or the global community in general. As one teacher stated, "I looked up some issues of water scarcity in various areas. I never really thought about it so I researched that." Other searches were specific to the country the students would represent during the simulation. Still others, concerned that their students may struggle with the complexity of the material, focused on finding leveled resources.

> So there was some times that, you know, like a period, looking up additional resources because I do have kids who struggle with reading and are not on reading

> level. So I had to find additional materials to help them understand the more complex text that was embedded in the curriculum.

When conducting these web queries, teachers reported that they turned to the GlobalEd 2 resource website, conducted their own searches, or did both.

Secondly, teachers reported to have reviewed the GlobalEd 2 curriculum and/or student workbook. As this teacher stated, “I went through the teacher’s curriculum quite a bit. I tagged the pages in the lessons I liked and went through the student workbook and tagged all the worksheets that I thought would be relevant.” A few teachers also recounted physically preparing the GlobalEd 2 student resources for their students (i.e. printing and binding the student workbook) ahead of the school year starting, since the resources were offered in electronic format. Additionally, several of the veteran GlobalEd 2 teachers declared that they reviewed lesson plans and activities they used with students during the previous year of the simulation in preparation for the current enactment.

Lastly, some of the teachers recruited to implement GlobalEd 2 along with other colleagues in their school, leveraged this opportunity to collaborate as they prepared for the beginning of the simulation. Some focused on getting a better handle on the content together, “…we really had to sit down for a while and read through the materials to learn about the issue area.” Others tended to focus on strategic planning, which involved determining how GlobalEd 2 would need to fit into their schedules given other curricular demands. Here a teacher explained this,

> Most of the preparation was just meeting with colleagues and just trying to figure out how we were going to bring that into the classroom along with the other curriculum. We reviewed the student workbook, the deadlines, and the calendar of events.

Table 11

Content Analysis Findings for Teachers' Own Preparation Represented by Percent Occurrence of Teachers' Responses

	PBL Implementation *n* = 19	Independent Learning *n* = 34
Teachers' Own Preparation		
No Preparation	21%	21%
Reviewed	74%	79%
Prepared Student Materials	16%	9%
Teacher Collaboration	21%	15%

Challenges. The analysis of the interviews, which focused on the challenges teachers reported facing when implementing GlobalEd 2, yielded three overarching themes. They represented challenges that were teacher-related, student-related, and challenges which were external and out of the teachers' control. Approximately a third of teachers from each group (42% PBL Grp, 35% Indep. Grp), predominantly first year GlobalEd 2 teachers, found implementing the simulation to be a difficult process. Some of the challenges mentioned, echoed those discussed earlier, when teachers talked about their level of comfort with implementing the simulation. Hence, teachers named challenges that stemmed from not feeling completely prepared, the unknown of this new venture, the complexity of finding the right balance between GlobalEd 2 and their other curricular obligations, and the overabundance of resources and teachers' freedom to choose what activities/resources they would use. In addition, making inclusion work with this level of complexity, also became an issue, as one teacher shared,

> I had a lot of ELL. I had a couple of very low Special Ed students that couldn't even do any of the work, and then of course that makes it much more difficult, because you want them to participate, but when they are in the group, they are actually making it difficult for the group to accomplish their work. So that was

> one of my biggest challenges and something that I struggled with throughout the semester is how do I balance that out with the kids.

Several teachers also disclosed that they themselves found the content challenging to some degree, "As a curriculum, I find it difficult for my students and honestly, for me too, because I was not used to this diplomatic language." The scientific aspect of the simulation was troublesome for some as well, as this teacher explained, "The science part, of course, is a little more challenging being a social studies teacher."

With regard to student-related challenges to implementation, the Independent Learning group teachers reported to struggle with these significantly more than the PBL Learning teachers. The differences in teacher responses across groups regarding student challenges is substantial, which could inform why implementation differences arose. Overall, 50% of the Independent Learning teachers expressed student related challenges to implementation in comparison to 31% of the PBL Learning group. The difficulty level of GlobalEd 2 was the most frequently mentioned struggle teachers voiced when discussing challenges their students faced. More than a third of Independent Learning teachers (35%) shared this concern, in comparison to a single teacher (5%) from the PBL Learning group. One teacher remarked,

> …the curriculum itself was just not meant for my students. I like the idea of, well, maybe we can give them this and try to get them to that, but I felt like it hindered their self-efficacy when the goal was to improve it.

Students appeared to have difficulty with different aspects of the simulation, whether it was reading, argument writing, or science. Teachers reported that they had to "break down the reading and really explain what they [GlobalEd 2 materials] were saying," and scaffold students' reading process. Alternatively, they needed to seek out additional resources, such as articles more closely aligned with their students' reading level, or substitute texts with, “a YouTube video or a podcast that helped them understand what was really going on.” In several, more extreme cases, teachers shared that since students could not “write a main idea” or “form complete sentences,” having them engage in argument writing, requiring claim-evidence-reasoning, was very hard. Another teacher revealed that, “…because my kids have no science background, they have no social studies background, it’s hard to teach somebody a concept when they don’t even understand the paper explaining the concept.” Others more generally questioned if students, especially the participating 7th graders, were developmentally ready for the level of complexity GlobalEd 2 offered. And although the simulation was spread out across 12 weeks, teachers reported that students had trouble keeping up with the pace.

Since some students found the experience very demanding, at a certain point, they became oppositional or resigned. One teacher commented that, “Once we started getting a little bit into it, they just felt like this was way too above and beyond their level and so they put up a wall with it.” Another teacher explained how students’ level of participation diminished over time, “I felt like we sort of dwindled out, because I think students felt a little bit defeated and a little burnt out by it at some point and I definitely noticed a drop in engagement when that happened.”

Transitioning to learning in a PBL environment was also found to be problematic for some students. There was a disconnect between what some students were used to and what this program challenged them to do. In one teacher’s words,

> I think it’s a challenge in the beginning when you set it up, because the students are in a very unfamiliar space, especially within this school context where they’re so used to this drill-and-kill kind of stuff, they had no idea of what they were doing.

If teachers were in a situation where they had to enact GlobalEd 2 along with a regular curriculum during the week, the GlobalEd 2 days were seen as, “Oh, no, this is going to be a harder day, because it’s going to be us [the students] doing the heavy lifting.” Hence teachers often brought up how difficult it was to obtain buy-in from the students and keep them engaged. Some mentioned having to succumb to more traditional means and offer students grades for completing certain assignments throughout the simulation. Other instances of disengagement appeared to be due to students’ uncertainty regarding how to proceed at certain points of the simulation, as this teacher illuminates,

> There were moments where they were just like “what am I supposed to be doing?” Or one partner is sending an email, but the other is kind of unsure of where to go from there…Sometimes other countries emailed them and they had something going, and others didn't, so I think those were the biggest [challenges]: time, and keeping everybody engaged.

Differing levels of engagement and unequal effort were also a struggle in students’ PBL groups. As often is the case with small group work, here too, teachers revealed that getting all students in a group to bear the same weight was a challenge. “I did have one kid in each group that worked extremely hard and a lot of the other kids were hitch-hikers…two groups were really great together, and the other two, it was one person in each of the groups,” explained one of the teachers.

In addition to teacher and student related challenges discussed during the interviews, external challenges or obstacles to implementation were also referenced by both groups and to an equal extent (79% PBL Grp, 79% Indep. Grp). These challenges were related to lack of time, technology, and cooperation from teachers and parents, as well as length of the simulation, and large class size. Overall, these impediments were mentioned by an equal number of teachers across both groups. Insufficient time to enact

GlobalEd 2 was the most frequently identified challenge in all. Restricted implementation time was most often the case when teachers had to simultaneously juggle two curriculums, GlobalEd 2, as well as their regular curriculum during the simulation.

> Because of these benchmark assessments with Common Core and us being aligned, it has limited my time. Last year I was able to dedicate some days four days, five days a week for a couple weeks in a row to GE2. This year it was two days a week was all I could get in, maybe three. Because if I didn't do my regular curriculum along with it, I was not going to meet the benchmark deadlines.

This was something teachers expressed anxiety over before the simulation even commenced, as was evidenced by their earlier declarations regarding their level of comfort in preparation for GlobalEd 2. Mandated testing and student preparation for those assessments was also a factor in the time teachers were able to devote to the simulation. And those, prepping students for the constitution test, had that additional burden.

> A lot of the tests we're taking are social studies and language arts mixed together. So when the students are presented with the Declaration of Independence on the test, the regular class is like, "well, we learned that already," whereas the GE2 class is like, "well, we read the Declaration of Human Rights, but that might not be the same thing."

Additionally, teachers complained that not being able to participate in certain live-conferences due to schedule conflicts, was detrimental to their students' progress.

Although GlobalEd 2 provided teachers with five tablets, one for each issue-area group, many teachers divulged that it was just not enough for students to be able to participate in the project fully. This often led to student disengagement and brought about classroom management issues.

> I found that sometimes having just one iPad per group wasn't enough and in our building where we are limited on available computers, sometimes that made it difficult for the kids to do research and so I found that some kids were idle and that led to other issues.

Some teachers had access to additional technology, however, others did not. In addition to the lack of technological resources, several teachers complained of having poor internet access, which also hindered participation.

Other problems, mentioned to a lesser degree, involved for example a push back from parents that were uneasy with their children participating in a program, unfamiliar in structure, which did not offer the concrete assessments they have come to expect from more standard curricula. Limited cooperation from outside teachers with regards to either allowing students to partake in conferences during their class-time or aiding the GlobalEd 2 teacher with content expertise (e.g. science) were also mentioned as grievances. The length of the simulation was also considered a challenge by some teachers. It was seen as the culprit for students losing interest or becoming fatigued. Lastly, large class size was reported to be an issue by a handful of teachers and it made small group work more challenging.

Table 12

Content Analysis Findings for Implementation Challenges Represented by Percent Occurrence of Teachers' Responses

	PBL Implementation *n* = 19	Independent Learning *n* = 34
Challenges		
Teacher Challenges	42%	35%
Student Challenges	31%	50%
External Challenges	79%	79%

Modification. The last category of responses provided an understanding of the extent to which teachers modified the curriculum, as well as the resources they tended to use. A great majority of the Independent Learning group teachers (68%) reported to have used predominantly GlobalEd 2 resources when implementing the simulation, in comparison to 47% of the PBL Learning group teachers. More than half of the Independent Learning group teachers (56%) however, stated that they modified the resources they used, which was only reported by 32% of the PBL Learning group teachers. One of the Independent Learning group teachers explained, "I didn't use the lesson plans, I used the materials and adopted it to what I wanted. I didn't really go through the lesson plans. Like in the beginning the intro to water stuff, I didn't' use any of that." In addition to using the teacher curriculum and student workbook, GlobalEd 2 videos and podcasts tended to be the most frequently mentioned resources utilized. Additional resources that teachers sought out on their own usually focused on specific matters related to the country their class was assigned or to aid students with argument writing.

Table 13

Content Analysis Findings for Curricular Modifications Represented by Percent Occurrence of Teachers' Responses

	PBL Implementation *n* = 19	Independent Learning *n* = 34
Modifications		
No Modifications	37%	38%
Modified	32%	56%
GlobalEd 2 Resources Predominantly Used	47%	68%
Combination of GlobalEd 2/Teacher Resources Used	37%	29%
Specific Resources	21%	35%

Chapter 5: Discussion

This chapter reviews the objectives, research questions, and quantitative, as well as qualitative findings of the present study. Implications of the findings are discussed in light of past research. Study limitations, as well as recommendations for future examination of the role PBL implementation plays in student learning are addressed at the conclusion of the chapter.

Summary of Research Questions and Discussion

Problem-based learning is one of several teaching and learning methods that has been brought to the forefront by educational reform efforts. It has a sound theoretical foundation supported by contemporary learning theories, and it encapsulates all the necessary elements to help prepare students for the challenges of the twenty-first century. Although the approach has great promise and has been adopted across various academic settings, it has been plagued by inconsistent outcome results (Albanese & Mitchell, 1993; Vernon & Blake, 1993; Walker & Leary, 2009). The PBL community has puzzled over the potential reasons for differences in study findings and theorized that variability in PBL enactment could be one possible culprit (Hung, 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009).

It is not difficult to postulate that PBL implementation might vary, since the method has been interpreted in a myriad of ways and various models of PBL have been proposed since its inception (Barrows, 1993). In addition, research has shown that in general, teachers adopt curricula to varying degrees, making modifications that suit their circumstances and needs (Rogers, 2003). Teachers' pedagogical beliefs, prior knowledge, experience, and self-efficacy have also been shown to influence how curricula are taken up and delivered (Carroll et al., 2007; Kirk, 1988). Moreover, with challenges specific to the enactment of PBL, such as teachers having difficulty embracing the facilitative role of a tutor (Grant & Hill, 2006), assuming a teacher-directed position when concerned with content coverage, (Moust et al., 2005), feeling unsure about how to assess student learning in PBL (Brinkerhoff & Glazewski, 2004), and transitioning students to become more self-directed (Gallagher, 1997), implementation fidelity is likely to suffer.

Consequently, the variability with which PBL is implemented could have an impact on student learning. Just as Barrows (1986) indicated, when instructional methods diverge from the original PBL design, it becomes unclear which learning objectives are being met. Due to poor implementation, the process may not stimulate students towards co-constructed and contextualized learning, which the method was designed to promote (Dolmans et al., 2005). In addition, with lacking or inadequate facilitative strategies on the part of the tutor, learning in PBL, especially for younger learners, could become cognitively overwhelming and ultimately, unsuccessful (Pedersen, Arslanyilmaz, & Williams, 2009).

Research aimed at illuminating what PBL implementation looks like and how it differs from one classroom to the next has been very limited, qualitative, and case-study based (see Liu et al., 2009; Pecore, 2013). Therefore, this study was initiated in order to investigate the matter quantitatively and provide an extensive account of PBL enactment based on more objective measures. Additionally, the investigation sought to explore if implementation-type was linked with differences in student learning outcomes, an important connection for which evidence has also been lacking from the PBL literature. Lastly, potential reasons for differential enactment were explored, in order to more comprehensively understand implementation efforts and attempt to improve them in the future.

Research Question One

RQ1. What implementation profiles emerge as teachers enact a PBL simulation in middle schools?

One of the main objectives of this investigation was to provide a look at what implementation patterns emerge as PBL is enacted. This was driven by the lack of such evidence in the PBL literature. As a part of this study, 53 teachers were systematically observed over the span of 12 weeks, implementing GlobalEd 2, a socio-scientific, PBL simulation, enacted in middle schools. The computerized tool utilized for observation allowed for the capture of teacher and student behaviors, including their interactions, during implementation. In order to explore what predominant instructional profiles emerge from the data, principle components analysis was first employed to condense the classroom observation variables into more encompassing instructional components. This was followed by cluster analysis, which allowed for the identification of structure within the data and reveal the most prevailing instructional patterns employed during implementation.

The principle components analysis identified five components, which accounted for 59% of the variance in the data. Component 1 involved students working collaboratively in small groups on research or project work while the tutor circulated the classroom and made surface-level comments regarding their progress. Component 2 exemplified instruction instances driven by students' needs and questions, where the tutor offered feedback related to students' work and/or their process. Component 3 characterized occasions where the tutor facilitated student learning through coaching and modeling based on the knowledge and reasoning students revealed as they engaged in various activities. Component 4 solely represented instances during which students worked independently. This excluded small group work and any tutor involvement. Component 5 showcased students engaging in reflection and/or self/peer assessment. This usually occurred as part of a tutor initiated discussion.

Teachers' averaged scores on each of the five components were utilized in the subsequent cluster analysis in order to identify the most prevailing implementation profiles. The analysis revealed two profiles, the PBL Learning profile and the Independent Learning profile, named based on their characteristics. The profiles greatly differed with regard to which instructional components were more or less visible during implementation. Tutors circulating among students as they engaged in research/project work (component 1) was a common element of instruction during implementation. This was a component teachers across the two profiles differed on the least and it was considered routine during classroom observations. The more nuanced elements of instruction, such as staying attuned to students' needs (component 2), providing them with appropriate guidance and coaching (component 3), and conducting reflective class discussions (component 5), were where the largest differences lay. These elements, considered in line with key PBL characteristics (Barrows, 1993), were prominent features of the PBL Learning profile, but not the Independent Learning profile. In fact, the extent to which students received coaching and guidance was the element of implementation teachers most greatly differed on between the two groups. Moreover, in comparison to the PBL Learning group, students of the Independent Learning teachers spent a significantly greater amount of time working independently, without the tutor's involvement or the support of their PBL group. Although some independent student work is warranted in PBL, while students conduct research for example, a more substantial portion of time should be spent in small groups, so that students have the opportunity to make sense of the material together, construct new meaning, and reach a deeper level of co-constructed understanding (Visschers-Pleijers et al., 2006). It appears then that the PBL Learning group teachers were more consistently engaged with their students and offered them a high level of support. The Independent Learning group teachers' involvement was lacking in comparison. The PBL Learning implementation profile can be considered aligned with the PBL model; however, the approach the Independent Learning group teachers took, does not. The findings showcase their enactment efforts as being more strongly driven by a hands-off approach to implementation. This type of approach has been shown to be counterproductive with graduate students undertaking PBL (Mifilin et al., 2000), and hence, can be presumed to be more of an issue with elementary age students, whose developmental level necessitates skilled guidance (Hmelo-Silver, 2010).

Case-study findings from prior research on PBL implementation, although limited, elucidate similarly stark contrasts in implementation. Pecore (2013) for instance, exemplified how among four high-school teachers enacting a PBL unit, two did so in line with constructivist beliefs, yet, the other two, implemented the unit utilizing traditional tactics. The author remarked that one of the teachers struggled with classroom management, but both teachers had a difficult time relinquishing control to students in order for them to be able to take ownership of their learning. Liu and colleagues (2009) also presented two pairs of contrasting case studies of a science, PBL unit being implemented with 6th grade students. The authors found two of the teachers' implementation styles to be reflective of key PBL elements (e.g. student-centered learning environment, tutor facilitation, student collaboration); however, this was not the case for the other two teachers. One of the teachers maintained a teacher-centered position, where direct instruction and student independent learning were the norm. The other teacher was considered to have taken a hands-off approach since she was mainly observed at her desk while students worked on the PBL project in pairs. The teacher interacted with the students primarily when they approached her with questions at which point, they were redirected to the student materials provided by the research team.

With the case study findings discussed above, but even more strongly evidenced by the results of this investigation, it is apparent that great variability can exist during PBL enactment. If PBL enactment is examined in light of the original PBL model (Barrows, 1996), it would not be considered implemented as intended if teacher-centered or hands-off approaches were the means of delivery. Since different pedagogical orientations, such as learning facilitation or knowledge transmission, often drive implementation and offer dissimilar learning opportunities, they could consequently impact student achievement (Gow & Kember, 1993).

From these portrayals, it is clear that PBL was not enacted equally from one class to another, hence not all students shared in the same PBL learning experience. It can be construed from the findings of this study that the students of the Independent Learning teachers did not obtain the same level of support as did the students of the PBL Learning teachers. This implies that they were not offered the assistance to develop the skills (e.g. self-directed learning, problem-solving, collaboration) necessary to be successful in PBL and self-sufficient, as would have been required by the students of the Independent Learning teachers (Hmelo-Silver, 2010; Savery, 2006). This is even more significant, since research has shown that the level of student engagement and what they do during self-directed study time is greatly influenced by tutor involvement (Dolmans et al., 1995). In addition, the experience of the Independent Learning students often lacked the collaborative aspect of learning in PBL, which is an important component of the method (Barrows, 1996). Small group work offers students the platform to activate their prior knowledge, deliberate about the possible solutions to the real-world problems they are tasked with solving, and ultimately, reaching a new level of co-constructed understanding (Greeno, Collins, & Resnick, 1996; Schmidt et al., 1989). These differences could have had a profound effect on student learning, yet limited data is currently available in the PBL literature to provide insight as to how different implementation styles influence student achievement. Therefore, the second aim of this investigation was to determine if enactment differences played a role in student learning. These findings are discussed in the following section.

Research Question Two

RQ2. After controlling for students' pre-writing assessment scores, does implementation type have an effect on students' post-writing assessment outcomes?

To examine if differential enactment of PBL could affect student learning, student pre and post scores on an argument writing task were analyzed in relation to the type of enactment students experienced, the PBL Learning or the Independent Learning. Analysis of covariance was employed in order to control for student pre-assessment scores and to include implementation type as a factor. The results revealed that there was a statistically significant difference between the groups on post-assessment scores with the PBL Learning group students outperforming the Independent Learning group students ($F_{(1, 909)} = 32.849$, $p < .004$).

These findings indicate that implementation type and more specifically, how teachers supported their students throughout this learning endeavor appeared to set the two groups apart. This is not surprising given the emphasis in the literature on the importance of guiding and scaffolding student learning in general, but especially in a demanding learning environment such as PBL (Gijselaers, 1996; Hmelo & Barrows, 2006). As PBL experts strongly emphasize, the role of the tutor as guide or coach is an essential aspect of successful learning in PBL (Hmelo-Silver, Duncan, & Chinn, 2007). It has been argued that the facilitative practices of the tutor may play a more critical role in student achievement than even tutor content expertise (Chng et al., 2015). Research has shown that students struggle with identifying, gathering, and synthesizing information needed to tackle the PBL problem (Pederson & Liu, 2002), and given their lack of domain-specific knowledge and self-regulatory skills, they are often unable to work through the problem on their own (Cho & Jonassen, 2002). Therefore, modeling meta-cognitive practices, scaffolding student learning, and promoting reflective practices is viewed as especially critical for younger learners that do not possess the tools to effectively engage in this type of learning independently (Hmelo-Silver, 2010). Research has shown that even students themselves report the most effective tutors to be those that assist them in the elaboration and integration of knowledge, that direct their learning process to some degree, stimulate interaction among tutorial group members, and hold students accountable for their work (De Grave et al., 1999).

From the findings of this study, it is plausible to state that, given the differential instruction students experienced during the implementation of GlobalEd 2, students' learning suffered and implementation fidelity was lacking for the Independent Learning group. However, given the importance of understanding implementation fidelity within the context in which it occurred as advocated by Durlak and DuPre (2008), this study further investigated the potential reasons for why implementation varied between the two groups by conducting a qualitative analysis of teachers' post-implementation interviews. These findings are discussed next.

Research Question Three

RQ3. What possible factors influenced the manner in which GlobalEd 2 was enacted?

To gain a bit more nuanced understanding of why teaching differed across the two implementation profiles identified in RQ1 and their differential impact on student outcomes isolated in RQ2, a content analysis of teacher interviews (n=53) conducted at the culmination of the GlobalEd 2 experience was conducted (RQ3). Teachers' philosophy, level of preparation, challenges to implementation, as well as curricular modifications, were the foci of the analysis.

The content analysis revealed some similarities across groups. In terms teaching philosophy, the vast majority of teachers in both groups spoke of supporting modern conceptions of teaching and learning, such as fostering a student-centered learning environment, promoting inquiry or discovery learning, and encouraging student collaboration, for example. With regard to how comfortable they felt with implementing the PBL simulation, roughly the same number of teachers across groups expressed feeling prepared versus unprepared post the professional development training. First-year, GlobalEd 2 teachers from either profile group declared feeling anxious and uncertain about implementation to a comparable degree (Indep. Grp 32% vs PBL Grp 26%) and equally reported experiencing a false sense of readiness, which they recognized once they began to implement the simulation in their classrooms. With regard to teachers' own preparation, 21% of teachers across both groups admitted to not preparing in any manner, but the great majority reported reviewing GlobalEd 2 materials before the simulation began. Lastly, common challenges, such as lack of time for implementation due to mandated testing or other curricular obligations, or limited access to technology, were also expressed equally by teachers of either implementation profile.

Even though similarities were found across both groups of teachers, there were also key differences that emerged from the data that can inform why implementation practices varied. For example, when discussing their teaching philosophies, the PBL Learning teachers greatly underlined the importance of creating a comfortable learning environment, in which students felt cared for. They expressed being of the mindset that all students could learn with the right kind of support. Although mentioned, these sentiments were voiced significantly less by the Independent Learning teachers. What the Independent Learning group teachers did emphasize to a much greater degree however, were student-related challenges to implementation (e.g. level of difficulty, transitioning to PBL, student collaboration). Specifically, 35% of the Independent Learning teachers, compared to a single teacher (5%) from the PBL Learning group, shared the fact that their students found the simulation too difficult, which they considered an impediment to enactment. Additionally, in terms of curricular modifications, although, the vast majority of the Independent Learning teachers expressed to have depended solely on GlobalEd 2 resources for their instructional support in comparison to approximately half of the PBL Learning teachers, they were also more likely to modify those resources. Hence, it is unclear how those materials were altered and if they maintained the learning goals they were designed to support. This could have impacted student achievement.

In looking across the different factors that could have played a role in why differences in implementation arose, it can be construed from these findings that the PBL Learning teachers had a somewhat different outlook related to student learning than the Independent Learning teachers. They tended to promote the “all kids can learn” attitude and focused on creating a caring learning environment for their students. As Schmidt and Moust’s (1995, 2000) research shows, tutor’s social congruence or the disposition of the tutor to engage with students in an authentic, empathetic manner, aiming to foster a safe learning environment for the open exchange of ideas is a key element of successful PBL implementation and one which has been found to help students excel in PBL (Chng, Yew, & Schmidt, 2015; Schmidt & Moust, 2000). Given that research shows that teachers' dispositions tend to drive their instructional (Schoenfeld, 1998) and implementation efforts (Durlak, 2010), perhaps it was the mindset of these teachers that propelled them to be more involved in their students' learning endeavor. And even though teachers across the two implementation profiles expressed supporting contemporary theories of learning, research has shown that teachers' espoused theories or beliefs related to their pedagogical approaches, often do not match their observed practices (Argyris, Putnam, McLain, & Smith, 1985; Strauss, 1993). This could explain the differences in implementation even when complimentary pedagogical beliefs were expressed.

In addition, 32% of the PBL Learning group, in comparison to just 15% of the Independent Learning group, was made up of teachers that were veterans of the GlobalEd 2 program. It could be the case that having this additional experience allowed the teachers to implement the curriculum with greater assurance and ease. Prior knowledge, experience, and self-efficacy have been shown to be instrumental in how programs are enacted (Carroll et al., 2007; Kirk, 1988). It could be the case as well, that the Independent Learning teachers, predominantly made up of first-time GlobalEd 2 implementers (85%), were overwhelmed by the experience. Many of the teachers expressed feeling uncertain regarding their preparation, as well as apprehensive about how the program would unfold in their classrooms. Other new teachers in the group could have potentially experienced the same insecurities, but given the possibility of response bias, which explains instances where participants share what they believe would be an acceptable response, rather than their authentic attitudes, did not express them during the interview (Pridemore et al., 2005; Wilson et al., 1998). This could have been a factor in differential implementation, since prior research has shown that teachers' self-efficacy correlates with effective pedagogy, specifically as it relates to science instruction (Tobin et al., 1994). Since the GlobalEd 2 curriculum dealt with the issue of fresh water scarcity, it required social studies teachers to facilitate science learning within a PBL framework. This was a challenge voiced by some of the teachers during the interviews. To add, teachers with high self-efficacy have been found to teach subject matter and related skills more thoroughly, facilitate student learning through open-ended questions more regularly, and assess student understanding on a more frequent basis than teachers with low self-efficacy (Riggs, Enochs, & Posnanski, 1991). Hence, given that the group was comprised mainly of new GlobalEd 2 teachers who were taking on the implementation of a challenging PBL program with a science component, their pedagogical efforts could have been negatively impacted. They might have even resorted to having students work independently to more easily manage the classroom.

Another element that could have influenced enactment was the fact that many students of the Independent Learning teachers were reported to have greatly struggled with the simulation. Teachers identified the difficulty level of the curricular materials, as well as the complexity of working within the PBL environment, as some of the challenges students experienced. It is important to mention that majority of the Independent Learning teachers taught in urban schools with more than half of the students enduring mid to high levels of poverty. Since poverty has been shown to adversely affect student learning and consequently, their outcomes (Engle & Black, 2008; U.S. Department of Education, 2001), it could have played a role in this case. However, even high poverty schools have been shown to increase student achievement, if certain efforts were made (Blazer & Romanik, 2009). For example, institutions where teachers have high expectations of students and believe that all students can succeed (Center for Public Education, 2005a), schools where students feel safe and receive emotional support, as well as encouragement (Kannapel & Clements, 2005), and schools where emphasis is placed on continuously refining the curriculum, improving pedagogy, and attuning instruction to students' needs (Center for Public Education, 2005a), have all been identified as factors that improve student success even under more difficult circumstances. These were not elements that characterized the Independent Learning implementation profile, however. Therefore, it is likely that the lack of such components in school contexts where they are especially critical, influenced student learning and led to limited student achievement.

Lastly, although this investigation focused mainly on looking at instructional characteristics to inform the extent to which the quality aspect of implementation fidelity was met, during teacher interviews, it became apparent that curricular adaptations could have also played a role in how the program was enacted. Although the Independent Learning teachers reported to have used GlobalEd 2 curricular materials to a greater extent than did the PBL Learning teachers, they also more frequently reported to have modified those resources. Presumably, they might have been attempting to make curricular adaptations to meet students' needs, yet given their inexperience with the program, were unsuccessful. Perhaps they altered the materials to be used by students independently, since small group work tended to be problematic for students in this group. The nature of the modifications and the degree to which they were altered is unknown, however. Nevertheless, not adhering to the design of curricula has been shown to impact student learning (Gersten et al., 2005), which might have been the case in this instance.

In summary, this investigation examined PBL implementation efforts and sought to explore if differences in enactment of PBL curricula existed. The study identified two contrasting implementation profiles. One which appeared to be in line with the original PBL model (Barrows, 1986), and the other, which seemed to lack several of its key components to a considerable degree, such as ongoing tutor engagement and guidance, as well as student collaboration. Independent student work was in fact, one of the underlying elements driving the composition of this profile. Given these differences, student outcomes were examined in light of implementation type and statistically significant differences were found between the two groups with better learning outcomes achieved by students whose implementation more closely adhered to the design of PBL.

Although the discrepancy between the enactment efforts can be construed as not meeting the quality component of implementation fidelity, with the reality of implementing any curriculum, but even more so one as markedly challenging as PBL, it is important to understand why differences emerged, so that the implementation or the design of the intervention can be improved in the future (Durlak, 2010). This analysis revealed that although the Independent Learning teachers might have had a somewhat different mindset with regard to what they felt their students needed, they also appeared to face more challenges than the PBL Learning group. They were predominantly new to the program and taught in more economically disadvantaged schools. The combination of their inexperience and uncertainty, coupled with enactment of a complex, PBL curriculum, which a great portion of their students found too demanding, could have led to feeling overwhelmed and assuming a hands-off approach.

Limitations and Future Directions

This investigation is ex post facto; hence data collection did not occur for the purpose of this particular study. This limited the analysis to an extent and should be taken into account when considering the results and study conclusions. This study was also exploratory in nature, which restricts generalizability of the findings and again, warrants restrain when interpreting results.

In this investigation, even though PCA and cluster analysis were valuable in reducing the large sample of data and identifying prevailing implementation profiles, some of the differences in teacher practices were ultimately lost in the analysis. Although this was exploratory research, it should be noted that several assumptions were violated when PCA was employed to extract main instructional components. Moreover, it is important to understand that differential cluster results can be obtained with the same data set based on the choices made by the researcher, such as applying different optimization criteria, for example (Distefano & Mindrila, 2013). To add, the selection and characterization of the clusters can be dependent on the investigator's interpretation. Similarly, the qualitative coding and findings can be subject to the researcher's construal. Although the qualitative coding scheme was peer-reviewed, the analysis was conducted solely by the investigator, which might be a limiting factor.

The observation tool employed in the study, although applicable, was not designed specifically for the purpose of examining implementation fidelity of the GlobalEd 2 curriculum. In the future, a more precisely attuned observation tool designed specifically for this purpose would be beneficial. Moreover, during classroom observations, observers were instructed to focus in on teacher/student interactions and small group work. However, they were also asked to remain as unobtrusive as possible, therefore, the extent to which certain elements of instruction and depth of exchanges were captured, could have varied. In the future, a tool that could capture not only teacher/student behaviors but also their discourse might be helpful in more precisely defining instructional profiles during PBL implementation.

Although teachers were expected to participate in major simulation activities and meet certain benchmarks along the way (i.e., positing of student proposals, participation in synchronous conferences…), the curriculum was otherwise unscripted and teachers were able to choose which resources they included and how they sequenced them over the course of implementation. The variability with which this was done could have impacted program outcomes. In addition, the curricular modifications teachers made and the external resources they incorporated could have also influenced the success of GlobalEd 2; however, the particulars of these adaptations are unknown. Therefore, incorporating these type of structural components (e.g., adherence to curricula), along with the process components (e.g., instruction quality) identified through this investigation, would offer a more comprehensive examination of implementation.

There are various other factors that could have concurrently influenced enactment and impacted student outcomes, yet, are difficult to precisely parse out. For instance, teacher and student demographic factors, teachers' previous participation in GlobalEd2, duration of enactment, student engagement, and so on, could have all been influential in this matter. Consequently, a more sophisticated analysis, such as hierarchical linear modeling for instance, should be employed in the future to more precisely pinpoint the mitigating factors in implementation.

Taken together, it should be considered that as we explore contemporary pedagogical approaches intended to address issues related to the ability of our education system to provide students with meaningful learning opportunities and a chance to develop 21st century skills, examining implementation fidelity is critical. We need to refrain from solely focusing on examining what works however, and consider the fact that within the context of a new pedagogical shift, exist teachers. Teachers that are tasked with enacting these new curricula in classrooms bound by a multitude of factors. Teachers that themselves may struggle with the change and with finding their place in a new learning environment. Rather than drawing a hard line with regard to implementation fidelity between what is acceptable and what is not, more comprehensive investigations can help us better understand which variables impact outcome results, provide a clearer picture of what is actually taking place during enactment, and ultimately, help with evaluating the value of a new pedagogical approach such as PBL. While this study provides a preliminary look at these various elements, more refined investigations of PBL implementation are still necessary to understand PBL's efficacy in different contexts and under varying circumstances; and in order to identify the teacher supports and training necessary to enact it with a level of fidelity vital to its success.

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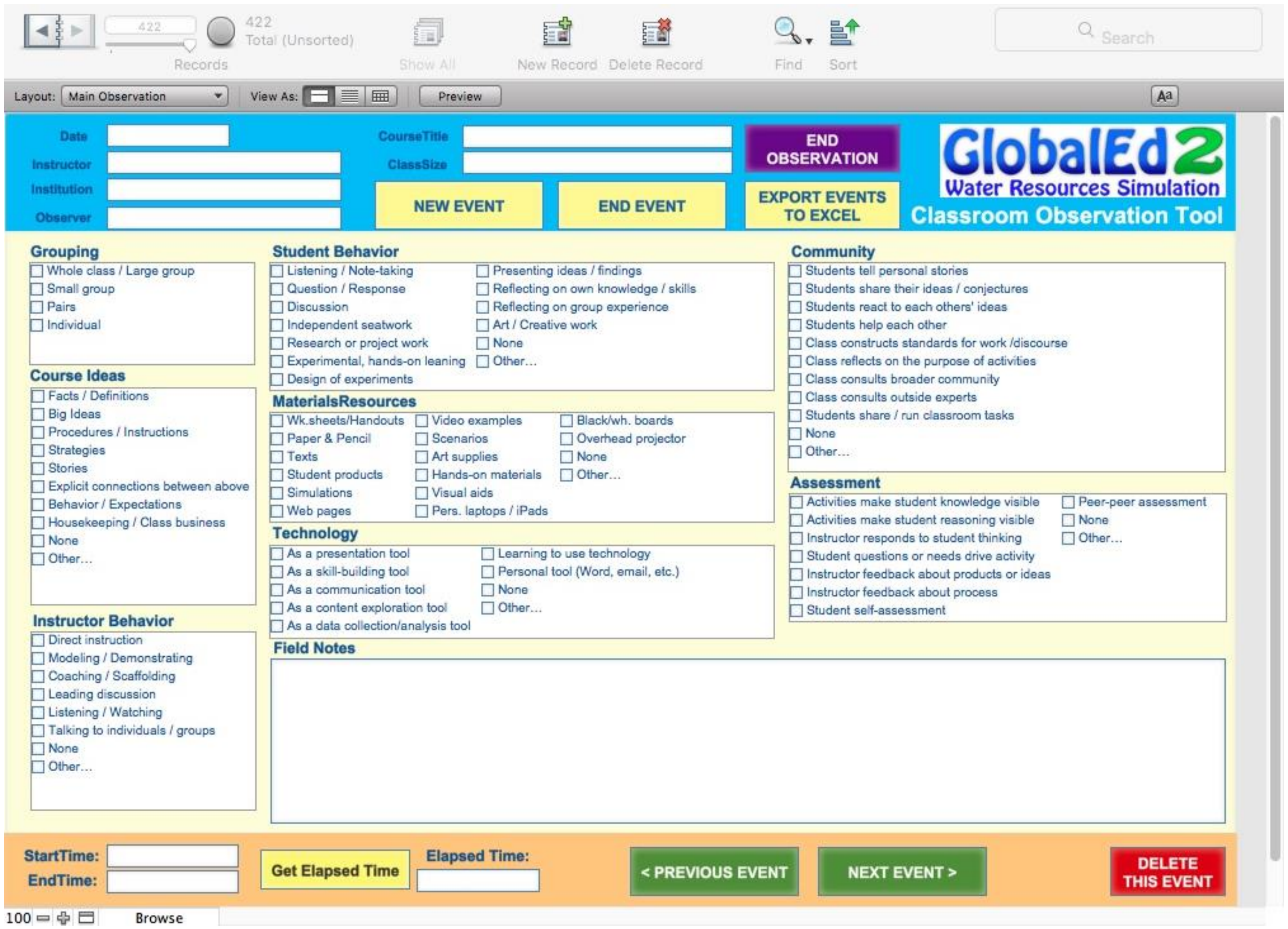
APPENDIX A

Screenshot of Observation Tool



APPENDIX B

Classroom Observation Codebook

Article I. Item Descriptions for the GlobalEd 2 Classroom Observations

Grouping:

Grouping refers to how centralized or how individualized the students' attention or activity is during the time block. Choose all that occur during the time block. Keep in mind that even though, students may be sitting in small groups due to the desk arrangement in the class, they may not be necessarily working in small groups. Choose grouping based on the nature of the activity.

Whole class: The entire class's attention is focused on the same speaker or event.

Small group: Students are working in groups and paying attention to some shared task or activity being undertaken by the group

Pairs: Same as small group, but in pairs.

Individual: Students are working singly, each paying attention to an individual task.

Course Ideas:

This section attempts to characterize the main intellectual focus or focuses of the students during this time block. *There should be a course idea for every time block, even those in which the instructor is not presenting material directly.* (Presumably the students are still thinking about *something*.) It may be difficult to discern the nature of the course idea in periods when students are working independently or in small groups, but you should try. It might help to listen in on discourse (if any) during the time. If the students are working independently, consider the nature of the task that students are working on. There may be multiple course ideas at play in any time block. Choose as many as you want. These are not mutually exclusive.

Facts/Definitions: This is factual or definitional information that comes from an authoritative source. For example, dates, times, names, statistics, physical characteristics such as boiling or freezing points. Definitions also fall under this category.

Big Ideas: These are large, important, central or explanatory ideas or theories for fields of study. For example, constructivism is a big idea in education or cognitive science. Evolution is a big idea in Biology.
Specific to GE2:
An example of a Big Idea in GE2 will be persuasive argumentation consisting of a

proper Claim, relevant and reliable Evidence, and Reasoning (CER). But since in GE2 various fields of study converge, you may encounter numerous Big Ideas occurring in tandem that explain the interaction between human and natural systems, as well as economy, religion, human rights, etc.

Students or teachers can relate big ideas to *facts* or *stories*. The big idea should somehow be linked to the instructor's goal for the lesson. Sometimes the big idea is the point that the lesson is working up to, and so it doesn't occur in all of the times for a class. Ask the teacher before you begin the observation what the Big Idea/s for the lesson will be, so you may more easily discern when it is at play. Ask yourself if it's explicitly on the table in the particular time block you're trying to code. *When you mark the big idea in the codes, let us know what it is in your field notes.*

Procedures/Instructions: Significant time during the time block is spent on learning how to perform a specific task, usually in a step-by-step manner. This task could be something that students will do in the class or out of class. There is little variation or choice to make in a procedure. An example in GE2 maybe students learning the step by step instructions on how to compose an argument by providing a claim, backed by evidence and reasoning (CER) or how to write an opening/closing statement.

Strategies: These are ideas about how to solve a particular kind of problem that might arise. Strategies are different from *procedures* because they assume that students will need to make choices about how to best proceed, and consider trade offs between different approaches. In GE2, an example of this may be students exploring best ways to conduct online searches to find the most relevant information. They may also discuss the best approaches/strategies to persuading their audience (this is more conceptual and involves a discussion about various approaches in contrast to learning the simple step-by-step CER composition mentioned under *Procedures/Instructions*).

Stories: Students are hearing, reading or writing stories.

Explicit connections between the above: This is when any of the above are explicitly connected, for example, when *facts* are explicitly related to *big ideas* or *procedures*.

Behavior/Expectations: Explicit discourse about expectations for student behavior or performance.

Housekeeping/Class business: This is when instructional time is taken to do non-instructional activities, such as taking the role or discussing pragmatic aspects of student work (such as how to use a class list serve or where to pick up assignments).

None: No course ideas seemed to be in play during this time block.

Other: You observed a course idea that does not fit into any of the categories above. Clicking on “other” will pop up a dialogue box on your screen that allows you to enter your own description of course ideas.

Instructor Behavior:

Note what the instructor was doing during the time block. Chose as many as apply.

Direct instruction: This means a lecture mode where the instructor addresses the class and presents course ideas or gives instructions. This code can overlap with other activities such as *Modeling/Demonstrating* (see next code) or *Question/answer* (see student behavior). Occasionally, the nature of the teacher’s prompting/questioning may resemble *Coaching/Scaffolding* even when done at the whole class level.

Modeling/Demonstrating: This happens when the instructor is showing how to do something. The instructor might model how a problem is solved, how a procedure is completed, how a particular learning activity can be conducted or how something works. In GE2, a teacher can model how to conduct a good internet search.

Coaching/Scaffolding: Coaching-scaffolding refers to cases when the instructor helps students accomplish a task as students do it. This will usually take place while the teacher circulates the class and checks in on what students are doing/talking about (during small group, pair, and individual work) and guides them based on their needs. *Coaching/Scaffolding* may occasionally be checked during whole class instruction when the teacher follows up with prompting questions to help guide student thinking.

Leading discussion: In a *discussion*, students are directly or indirectly responding to each other’s and the teacher’s ideas. When a professor is *leading discussion*, he or she is moderating this conversation, either by calling on individuals or seeding ideas into discussion. Leading discussion is different from *question/answer* interactions. In *discussion*, the ideas and discourse are more open-ended. In a discussion, the teacher is usually not fishing for a specific answer, but allowing and encouraging an exchange of ideas. See also *Discussion* under Student Behavior.

Listening-watching: The instructor is listening and watching what the students are doing. The instructor may do this as students engage in *discussion, individual seatwork, presenting ideas/finding* or other similar behaviors.

Talking to individuals/groups: The instructor is talking to individuals or groups about issues pertaining to the individual/group and not the class as a whole. If the instructor answers a question during *whole class, direct instruction* or other instructional activities this code should not be marked. Generally, this code should only happen when the class is working in small groups, pairs or individually. Talking to individuals/groups can take many forms. The instructor could be answering questions, giving individualized feedback or going over the fine points of assignments. This code can overlap with other activities such *modeling/demonstrating* or *coaching/scaffolding*.

None: You cannot perceive any instructor behavior. Perhaps he or she is out of the room or sitting at their computer, not engaged with the students.

Other: The instructor may be doing something not on this list. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

Student Behavior:
Record all student behaviors that were observed during the 5-minute block.

Listening/Note taking: This should be checked when the primary behavior of the students is listening or otherwise taking in information. The student role here is primarily passive, though they may be taking notes.

Question/Response: Students are participating in question/response exchanges. Generally, these exchanges elicit closed-ended factual information or clarify points made. A student can participate in such an exchange by either asking or answering questions.

Discussion: Discussion is different from *question/response* in that it is more open-ended and can include many people building off of each other's ideas. In a discussion, there are many ways of contributing beyond question and answer.

Independent seatwork: Students are working independently. They may be answering questions, filling out a worksheet or alike (without conducting research). This will be a less involved activity as compared to *Research or project work*.

Research or project work: This is when students are working on a group or independent project during class. They may be conducting research to gather information for their projects. This will be a more open-ended and involved activity as compared to *Independent seatwork* (e.g. doing research, work-shopping essays).

Experimental, hands on learning: Students are exploring content ideas by using physical objects.

Design of experiments: Students are actually designing experiments.

Presenting ideas and findings: Students may either be reporting on an observation they made, project related experience they had (such as taking part in a GE2 conference) or a project/assignment they completed. They should be presenting ideas that they have already thought through.

Reflecting on own knowledge - skills: This category should be used when students make explicit reference to how their thinking has changed, how their thinking has been influenced by engaging in a certain activity, or how their ideas have developed over time. This will be metacognitive in nature. This could be done orally or through a written assignment.

Reflecting on group experience: This category should be used when students make reference to their experiences (or any change or growth) associated with activities or processes the group has engaged in. The group could be the class as a whole, or the group can be a small project group within the class. This could be done orally or through a written assignment such as journaling.

Art/Creative work: Students are making or adding to some created artifact. This could be making a personal artwork, illustrating a story or adding to some shared creative artifact such as a mural or even a musical improvisation.

None: There was no observed student behavior during the time block observed

Other: The students are doing something not on this list. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

Materials and Resources:

In this category, you should make note of the materials used in classroom activities.

Worksheets/Hand outs: These are materials that ask students to answer questions or perform other discrete tasks. If possible, please collect copies of these materials. *Worksheets/Handouts* may also include third-party prepared workbooks.

Paper & Pencil: These are student-supplied devices for taking notes or making calculations.

Texts: Texts could be textbooks, articles, or other prepared written information that students use in class. These are prepared by a third party (such as a publishing company) and not the instructor.

Student products: This is work produced by the students. This will include work produced by students in the class you are observing, as well as work produced by students in a class at a distance (e.g. students' online communiqués).

Simulations: Simulations allow students to better understand some system by manipulating some aspect and seeing resultant changes. Simulations are usually computational, though some physical models can also serve as simulations. This should not to be confused with the online messaging that teachers may refer to as part of the GE2 simulation. In GE2, this could be a simulation of how desalinization works for example.

Web pages: These are on line texts.

Video examples: These are any video segments used in class.

Scenarios: Scenarios should be used when the students are presented with or bring written examples or scenarios to class.

Art supplies: Paints, pencils, glue, colored paper etc…

Hands on materials: These are any physical objects that can be manipulated to help with building understanding or completing course tasks. For example, hands on materials could be math manipulatives or measurement devices.

Visual aids: These are any other prepared materials that the instructor shows to class members in order to make a point. They could be pictures, diagrams, models, maps, etc.

Personal laptops/iPads: This category is used when students use laptops or tablets to perform classroom tasks such as taking notes, making calculations, conducting online research, etc.

Black/Whiteboards: This is any writing surface used publicly.

Overhead Projector: These are devices that allow for the projection of information. This may also include a Smartboard.

None: No materials were used during the time block

Other: materials other than the ones above were used during the time block. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

Technology:
Describe if and how computational or other electronic technology was used during the observation block.

As a presentation tool: This is to be used if the technology is used primarily to help the instructor or students present or convey course ideas.

As a skill-building tool: This should be selected when technology is being used to help students build or become automatic with certain skills. Examples might be quiz-practice programs.

As a communication tool: Choose this when the class uses technology for in-class communication or for communicating with others outside the classroom (such as sending communiqués to other students in the simulation). This may also include

Google Docs when used to collaborate. You may also use this code when the instructor is using a technology that makes student ideas public (such as Inspiration).

As a content exploration tool: This is to be used when students and/or the instructor use technology to explore classroom content. This can be done through accessing information (conducting online research, unpacking communiqués), running simulations, watching videos, or alike.

As a data collection – analysis tool: This should be selected when students use technology for data collection or analysis. Statistical packages for data analysis would fall under this description, as would any creation of graphs or charts with technology.

Learning to use technology: This should be selected when students are simply learning how to use a certain kind of technology rather than using it to build knowledge. An example might be a teacher leading students on how to use a particular app or conduct online searches (actually performing a Google search to find relevant information would be captured under *As a content exploration tool*).

As a personal tool: Students are using laptops or other computers on their own initiative rather than as directed by the teacher. These tasks could include note taking or making calculations, or checking email. If students are using a Google Doc to write their own ideas down, but are not collaborating with others, this code may also be used.

None: No technology was used during the time block.

Other: Technology was used to serve another purpose during the time block. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

Community: This category is for recording the nature of community-building activities (if any) in the classroom.

Students tell personal stories: This is to be used when students are referring to events in their own lives as in giving real-life examples.

Students share their ideas/conjectures: This category should be selected when students express their ideas, make inferences, share their opinions or questions regarding the content. This category may also include cases when students express opinions with a show of hands or a ballot.

Students react to each other's ideas: This is to be used when students explicitly reference each other's ideas in conversation, or debate or discuss their ideas and/or opinions.

Students help each other: This is to be used when students are helping each other, often times through group work or even during a discussion, when a student chimes in to help another student express a point for example.

Class constructs standards for work-discourse: This is to be chosen when the class as a whole has a hand in constructing standards for classroom activity. Examples include the construction of a rubric for a class assignment, or explicit building of criteria for what kinds of discourse is wanted in a particular area.

Class reflects on the purpose of activities: This is a conversation among the class members and the instructor as to why any particular activity is being done, usually relating it to the broader context of learning (instructional goals, real world utility, etc.). This category is to be chosen when the students in the class express thoughts about this, not when the instructor merely says it.

Class consults broader community: This happens when members of the local community come into the classroom as local experts, classroom visitors, presenters, judges for projects, etc. The idea here is to connect the community of the classroom with its broader community that the school is situated in.

Class consults outside experts: This is most likely to happen if the class consults an expert in the content area that is being studied. The idea here is to connect the classroom with a broader community of practitioners and experts in that domain.

Students share/run classroom tasks: This is when students take responsibility for getting everyday classroom tasks done, taking responsibility for managing supplies or cleaning up for example.

None: You saw no community-building practices in this time block.

Other: You saw a different kind of community building practice during this time block. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

Assessment:
Instructors may use various strategies to assess and react to student thinking. Rather than formal assessments (grades, written comments) this category is interested in any kind of ongoing assessment that an instructor might use in the course of an everyday class. Using a show of hands, recording student ideas on the board, polling student ideas may all be recorded as assessment.

Activities make student knowledge visible: Classroom activities serve to make students' knowledge public or apparent to the instructor. Student knowledge or mastery of *facts, definitions, procedures* or components of *big ideas* are exposed publicly through classroom activity. This could be done through taking a poll, posting results or asking multiple students to chime in on the same question. Note that not everything that is exposed through a poll or the like is *knowledge* (or *reasoning*—see below). For example the instructor could take a poll of student opinions or experiences ("Who watches the news every night?" for example) in the course of classroom activity in order to make or reinforce a point. Soliciting that information is not the same as making knowledge visible. In some cases, students may be asked to express what they do not know about a particular topic or present questions they have regarding the content, in these instances, this code should also be checked.

Activities make student reasoning visible: This item differs from *Activities make student knowledge visible*, this exposes student reasoning. The same kinds of activities may be used, but the focus is on how the students think about course ideas, not their mastery of information. These activities should not be rhetorical questions, but should seek to genuinely inform the professor's understanding of the thinking going on in his or her classroom. An example of a question designed to surface student reasoning would be "Can you explain how you arrived at that conclusion?"

Instructor responds to student thinking: This is used when the instructor responds to student thinking or reasoning. This could happen when the instructor challenges, reinterprets, or expands student thinking.

Student questions/needs drive activity: A significant amount of activity in this time block is determined or strongly influenced by expressed needs or the questions of the students.

Instructor feedback about products or ideas: This occurs when the instructor provides evaluative feedback regarding student products or ideas. These products could be written assignments, but they could also be work or ideas that students construct or contribute in class. Note: Emphasis is on feedback about knowledge.

Instructor feedback about processes: This should be chosen when the instructor gives evaluative feedback on how individuals, the group as a whole or subgroups are performing essential tasks. Note: Emphasis is on feedback about skill.

Student self-assessment: This happens when students reflect on or examine, publicly or privately their own knowledge, progress or performance. This may take different forms, students may be asked to check their work against a rubric for example or they could be asked to reflect on what they know and don't know, how their thinking has changed or how it has been influenced by engaging in a particular activity.

Peer-peer assessment: This happens when students reflect, publicly or privately on each other's progress or performance on classroom tasks.

None: No ongoing assessment activities were observed in this time block.

Other: You observed other ongoing assessment activities. Clicking on ***other*** in any category will pop up a dialogue box on your screen that allows you to enter your own description.

APPENDIX C

Teacher Interview

GENERAL PEDAGOGY

1. How would you describe your overall teaching philosophy?

2. In general, in what ways do you tend to assess your students? Are there instances where your students assess themselves and/or each other?

3. Would you consider your classroom to be that of a community of learners? If so, how?

GE2 PREP

4. After the GE2 training, how prepared and comfortable did you feel to implement the GE2 simulation?

5. Before the simulation began, was there anything that you did to prepare yourself for the implementation of the simulation and for teaching within a problem-based learning environment?

GE2 PEDAGOGY

6. Did participating in GE2 influence the manner in which you taught social studies and the way you structured your classroom?

7. What resources did you tend to use during the GE2 project (were they GE2 resources or ones you created)? When you used GE2 lesson plans, did you tend to use them as they were or did you modify them in any way?

8. Can you describe an activity that you used during the simulation and walk me through how you lead the activity?

9. How did you assess and scaffold your students' learning throughout their participation in GE2?

GE2 STUDENT EXPERIENCE

10. In general, what do you think your students got out of being involved in the GlobalEd 2 project?

11. How did the GE2 simulation improve your students' writing, understanding of science concepts, and social studies concepts, and improve their technology skills?

FEEDBACK

12. Where there any challenges that you faced in implementing the GE2 simulation (these could be at the curriculum, student, classroom, school level)?

13. How do you feel about the duration of the simulation as a whole (14 weeks) and each of the three phases in particular (Research Phase – 6 weeks, Interactive Phase – 6 weeks, Debriefing Phase – 2 weeks)?

14. What do you feel was the level of student engagement throughout the three phases of the simulation? Was there ever a point when students became disengaged? If so, why do you think that was?

15. What did you like best about the GE2 process and how can we improve the simulation and your and your students' experience?

APPENDIX D

Persuasive Essay Task

Persuasive Essay on Social Studies and Science

Prompt: The world is in danger of running out of fresh water. Do you think this is true? Do you agree or disagree with this statement? Why?

Assignment: Write a **persuasive** essay stating your point of view on the prompt above. Give evidence to support your answer and provide your reasoning why this evidence supports your claim. Use your knowledge about water, science, world geography and cultures to help you write your response. You will have a total of 30 minutes to complete your essay.

Directions
Take a few minutes to plan your paper. Make notes on the other side of this page. An outline may help you plan well.

1. Decide if you **agree** or **disagree** that the world is in danger of running out of fresh water. Take **one** position on this issue.

2. Think of evidence that supports your position.

3. Think of reasons why this evidence supports your position.

4. Organize your ideas carefully.

5. Manage your time to allow for **writing** a closing statement.

After you have planned the paper, begin to write. Finally, proofread your finished paper to check for correct sentences, punctuation, and spelling.

APPENDIX E

Persuasive Essay Rubric

Section 1.01 GlobalEd 2 Writing Rubric: Claim-Evidence-Reasoning

Section 1.02 This Rubric is designed for the pre- and post- GE2 essay prompts.

Raters: This is about CHAINS of logic that need to tie together. Quickly review the essay before scoring. If there is more than one chain, Identify the BEST single logic chain in the essay and score only that one. If there are multiple chains that are all the same quality, pick the first of these as the chain to code.
Of high Importance – DO NOT BE SWAYED by the "look" or length of an essay. Read it carefully! Neatness and quantity are NOT proxies for a well-formed essay! There are MANY examples of neat essays free of spelling and grammatical errors that contain a lot of content, but that are not advancing CER chains in a systematic way… You have to really concentrate on what CERs the student is trying to advance and divorce that from aesthetics!

What is a C-E-R logic chain? There are 3 parts to a CER logic chain: (1) The Claim; (2) The Evidence; and (3) The Reasoning. The claim is an assertion or conclusion that addresses the original inquiry question. The evidence is scientific data that supports the student's claim. This data can come from an experiment that students conduct or from another information source such as a journal or news article, a textbook, or a data archive. The data needs to be relevant to, and sufficiently support, the proposed claim. The reasoning provides a justification that **links** the claim and evidence and illustrates why the data counts as evidence to support the claim by using the appropriate scientific principles.
For a complete C-E-R all the components must be linked together, though the actual ORDER of the 3 components may vary form the standard C-E-R. It is NOT your job as a rater to re-structure the chain for the student. It must be a logical chain. You are NOT to "cherry pick" across the essay and "find" CER components that are present somewhere in the essay, but not intentionally linked by the student. Do NOT select unrelated links in the chain to increase the rating of the essay. The chain must be the Intent of the student BUT a chain CAN be inferred by the rater.

Example of a CER chain:

Claim	Evidence	Reasoning
"It is the position of the environmental committee that carbon sinks are an effective measure to reduce the amount of greenhouse gases in the atmosphere."	*"there have been successful uses of carbon sinks documented. For instance, forests planted in China 20 years ago have proved to be massive absorbers of carbon dioxide gas. "*	*"…by increasing the number of carbon sinks, we can reduce the amount of carbon dioxide as reduce the greenhouse effect."*

Section 1.03

Section 1.04Student Essay Assignment

Prompt: The world is in danger of running out of fresh water. Do you think this is true? Do you agree or disagree with this statement? Why?

Assignment: Write a **persuasive** essay stating your point of view on the prompt above. Give evidence to support your answer and provide your reasoning why this evidence supports your claim. Use your knowledge about water, science, world geography and cultures to help you write your response.

RUBRIC Key

Section 1.05Essay Position (0-2)

What is the student's position in the essay?
0 = absent position or no position

Student has written about something unrelated to the topic of water shortages
Student has no position, for or against…. Agree or disagree.

1 = Support the statement – True; "We are running out of fresh water."
2 = Rejects the position; Not True; "We are **not** running out of fresh water."
3 - Student presents both positions (For and Against) BUT takes no position of what he/she believes; "The world may or may not be running out of fresh water."

Section 1.06Claim (0-2)

The Claim is NOT a restatement of the prompt. The Claim is the "*causal connector*" – the "*because*" of the essay. It is the statement addressing WHY they believe the world is or is not running out of fresh water. It does NOT have to contain a Direct Causal Connector. You as the rater can infer the missing the word "because".
0 = absent

Cannot discern a claim or claim DOES NOT RESPOND TO PROMPT.

1= Partial

The Claim can be inferred.

EX1: "Freshwater is being polluted…" – Here, you can infer that they are stating that the freshwater problem is due to pollution, although they have not expressly made that connection for you.

2 = Well developed

The Claim is clearly identifiable
EX1: "Water shortages world-wide are being caused by increased population."
EX2: "The world is running out of fresh water because there are more people than ever before."

Section 1.07Evidence – For the presented claim (0-3).

If there is no Claim, THEN there can be no Evidence or Reasoning
0 = Absent

None provided for the presented Claim
The evidence is missing or unrelated to the Claim.

1 = Partial

Provides some Evidence, but it is either weak or incomplete or the Evidence is related to the Claim but it requires an inference, rather than being clearly stated. The Evidence does not have to be specific data.

EX1: "People like me waste a lot of water"
EX2: "People waste water"
EX3: "Australia has a huge drought"

2 = Well developed

The evidence is related to the claim and does not require an inference; clearly stated.

EX1: "Since the turn of the century the population of the world has doubled."
EX2: "Due to climate change powerful storms are changing the fresh water distributions"

3 = Data Included for a 2 response

This is reserved for the highest level of evidence.
Clearly stated ***and** includes stated Reasonable Data.*

Section 1.08Reasoning (0-2)

If there is no Claim, THEN there can be no Evidence or Reasoning. Reasoning **MUST** provide the **LINK** between the Evidence and the Claim. The essay tells how the Claim and Evidence are linked together. This section must address the WHY portion of the prompt.

0 = Absent

Provides no reasoning LINKED to Claim and Evidence

1 = Partial

Reasoning LINK is incomplete or weak or clearly incorrect

EX: "This is why the population of the world matters."

2 = Well Developed

Reasoning is well thought out and clearly **LINKS** Claim and Evidence.

EX: "More people on earth means more people using freshwater – more people needing water is depleting our freshwater supply."

Section 1.09 Holistic Section

Scores in this section are for the overall essay. Score the following sections based on the holistic nature of the essay on Addressing the Opposition, Organization, Science Content and Social Studies Content.

Section 1.10Addressing the Opposition (0-2)

This can occur anywhere in the essay, and does not need to be directly attached to the CER chain being coded above.

0 = Absent

No attempt to address the opposition OR opposing positions.

1 = Partial

The opposition is addressed, but it is done in an incomplete manner. No counter argument to the opposition presented.

Ex: *" ... of course there are people who disagree…"*

2 = Well Developed

Addresses the opposition AND provide counter arguments.

Rationale – you recognize there are alternative views out there and you provide counter arguments refuting the opposition.

Ex: "Other people believe we have plenty of water, many of these individuals look at the ocean and see plenty of water, however the water in the oceans is salt water, not fresh water and cannot be used for human consumption."

Section 1.11Organization (0-2)

Score the organization of the essay holistically. You are judging the organization of the entire essay, overall.

0 = Disorganized, difficult for rater to follow coherent flow

1 = Clear attempt at organization but not optimized, thoughts not clearly flowing, *may or may not have a conclusion.*

2 = Coherent structure, including a conclusion

Section 1.12Science Content (0-3)

Score the science content of the essay. You are judging the science content of the entire essay, overall (climate, water cycle, pollution, earth science topics – ground water, etc.). Did the student mention science concepts?

0 = Absent

1 = Mentions a low level science content; colloquial terms

Examples: pollution, wasted water, lakes, streams oceans, environment

2 = Partially present but not complete OR using multiple scientific terms;

Examples: Point and non-point pollution; agricultural run-off; desalination; desertification, etc.

3 = Complete and Strong

Either an elaborated, accurate discussion of 1 science topic **OR** at least THREE (3) scientific terms (see 2 above).

Section 1.13Social Studies Content (0-3)

Score the social studies content of the essay holistically. You are judging the social studies /social systems content of the entire essay, overall (geography, politics, economics, culture, human rights …). Did the student mention social issues in their essay?

0 = Absent
1 = Mentions a low level social content; colloquial terms
EX: People working together; around the world; community
Generally mention the environment/landforms – lakes, rivers, …
All we need is money and we can fix the problem.

2 = Partially present but not complete OR using multiple social terms;
EX: Help from leaders around the world; regulation, laws/policies
They tie the environment to geography, such as tying deserts, rain forest, etc. to water resources in different parts of the world.
Some countries have a lot of money and others have very little money.

3 = Complete and Strong
Either an elaborative discussion of 1 theme of social science **OR THREE** different social systems **at a level 2** – economics, geography, politics…

APPENDIX F

Codes Occurring Less Than Five Percent of the Time and Removed from Analysis

Code Category	Code Name	Percent Occurrence
Student Behavior	Art/Creative work	1%
Student Behavior	Design of Experiments	0%
Student Behavior	Experimental/Hands on learning	0%
Course Ideas	Stories	4%
Community	Class constructs standards for work/discourse	0%
Community	Class consults broader community	1%
Community	Class consults outside experts	0%
Community	Class reflects on the purpose of activities	2%
Community	Students share/run classroom tasks	3%
Community	Students tell personal stories	4%

APPENDIX G

Pairs of Codes Combined for Analysis

Code Category	Original Code	Percent Occurrence	Combined Code
Grouping	Small group	52%	Small Group/Pairs
	Pairs	7%	
Teacher Behavior	Coaching/Scaffolding	26%	Coaching/Modeling
	Modeling/Demonstrating	8%	
Student Behavior	Reflecting on group experience	11%	Group and/or Individual Reflection
	Reflecting on own knowledge/skills	6%	
Assessment	Instructor responds to student reasoning	24%	Instructor Responds to Students Needs and/or Students' Needs Drive Activity
	Students needs drive activity	4%	
Assessment	Instructor feedback about products	23%	Instructor Feedback About Products/Process
	Instructor feedback about process	14%	
Assessment	Student self-assessment	6%	Self/Peer Assessment
	Student peer-assessment	5%	

APPENDIX H

Assessment of Cluster Stability

Principal Components (PC)	Original Centers *n* = 53		Subset 1 Centers *n* = 26		Subset 2 Centers *n* = 27	
	PBL	Ind.	PBL	Ind.	PBL	Ind.
PC1 – Research/Project Work as Tutor Circulates	0.11	-0.08	.18	-.15	.01	-.04
PC2 – Q/R Based on Student's Needs	0.36	-0.21	.26	-.29	.53	-.19
PC3 - Tutor Coaches Students	0.69	-0.37	.67	-.30	.58	-.43
PC4 - Student Independent Work	-0.33	0.19	-.44	.00	-.16	.35
PC5 - Reflection Through Class Discussion	0.30	-0.18	.33	-.26	.26	-.15

***Note*.** QR = question/response session

APPENDIX I

Qualitative Coding Scheme Used in Interview Analysis

Category	Theme	Code
Philosophy	Contemporary Pedagogical Views	Inquiry/discovery learning
		Student-centered learning
		Student collaboration
		Facilitating/scaffolding learning
		Project/problem-based learning
	Traditional Pedagogical Views	Teacher-directed
	Supportive Learning Environment	All kids can learn
		Meeting students' needs
		Caring learning environment
	Discipline Specific Focus	Making connections to real world and global community
GlobalEd 2 Preparation	Fairly Prepared	Prepared
		Somewhat prepared
	Not Prepared	Not prepared
	Falsely Ready	Falsely Ready
	First-year Anxieties/Uncertainties	Anxiety/uncertainty related to implementation
		Anxiety related to technology
		General confusion
	Overwhelmed by Difficulty and Amount of Curricular Resources	Overwhelmed by level of difficulty of curricular resources
		Overwhelmed by amount of curricular resources
	PD Feedback	Real-life example of implementation
		Sequenced lessons plans
		Difficult PD
		Benefited from interactive part of PD
		Benefited from accessibility of PD materials throughout implementation
	Felt supported	Felt supported by team staff
		Felt supported by teachers
Teachers' Own Preparation	No Preparation	Did not prepare
	Reviewed	Reviewed teacher curriculum

		Reviewed online resources Reviewed previous lesson plans
	Prepared Student Materials	Printed student workbooks
	Teacher Collaboration	Collaborated with other teachers for implementation
Challenges	Teacher Challenges	Teacher difficulties - general Teacher difficulties – 1st year
	Student Challenges	GlobalEd 2 too difficult Transitioning to PBL Collaboration Student discussion
	External Challenges	Limited time Limited technology Lack of cooperation - parents Lack of cooperation - teachers Length of simulation Large class size
Modifications	No Modifications	Did not modify curricular resources at all
	Modified	Modified some curricular resources
	GlobalEd 2 Resources Predominantly Used	GlobalEd 2 resources were predominantly used
	Combination GlobalEd 2/Teacher Resources Used	Combination of GlobalEd 2 and teacher created or found resources used
	Specific Resources	GlobalEd 2 videos, podcasts, website Resources specific to assigned country

VITA

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EDUCATION

2020 **Ph.D., Educational Psychology**, University of Illinois at Chicago
Dissertation: Curricular Implementation Patterns and Their Potential Influence on Student Achievement

2012 **M.Ed., Measurement, Evaluation, Statistics, and Assessment**, University of Illinois at Chicago

2003 **B.A., Psychology**, University of Illinois at Chicago

PUBLICATIONS – BOOK CHAPTERS/PROCEEDINGS

Lynn, L. J., Lawless, K. A., Brown, S. W., Brodowinska, K., Mullin, G., Powell, N., Richards, K. A., Boyer, M. A. (2014). Science vocabulary development in a problem-based learning simulation. *National Teacher Education Journal 7*(3), 5-12.

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Lawless, K. A., Brown, S. W., Lynn, L. J., Bruscianelli, K.B., Riel, J., Oren, J. (2016, April). *Improving written argumentation through web-based, interdisciplinary* *simulations: The GlobalEd2 Project.* Paper presentation at American Educational Research Association, Washington, DC.

Oren, J., Lawless, K. A., Brown, S. W., Bruscianelli, K.B, Riel, J., Lynn, L. J. (2016, April) *Do teacher's behaviors change while leading a collaborative classroom?* Paper presentation at American Educational Research Association, Washington, DC.

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Lawless, K.A., Brown, S.W., Brodowinska, K., Lynn, L., Khodos, G., Mullin, G.P., Yukhymenko, M., & Boyer, M.A. (2012, June). *Distributed learning environments: Cooperative/collaborative learning.* Paper presented at EdMedia 2012, Denver, CO.

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Lynn, L. Lawless, K.A., Brown, S.W., Boyer, M.A. and the GlobalEd 2 Team, (2012, May). *Development of science vocabulary in an online learning environment.* Poster presented at the Association for Psychology Science: Annual Convention, Chicago, IL.

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Yukhymenko, M., Brown, S., Boyer, M., Lawless, K.A., Cutter, A., Mullin, G., Williams, G., Powell, N., Enriquez, M.F., Brodowinska, K., O'Brien, D., Khodos, G. (2010,

Oct). *PBL in action: Effects of GlobalEd 2 on students' motivation related to science and social studies in middle school.* Paper presented at the 2010 Northeastern Educational Research Association Conference, Rocky Hill, CT.

Brown, S.W., Lawless, K.A., Boyer, M.A., Cutter, A., Brodowinska, K., O'Brien, D., Williams, G., Powell, N. & Enriquez, M.F. (2010, May). *GlobalEd 2: Using PBL to promote learning in science and writing.* Poster presented at the Association of Psychological Science Conference, Boston, MA.

Brodowinska Bruscianelli, K., Lawless K. A., Boyer M. A., Brown S. W., O'Brien D. W., Williams, G., Powell, N., Fernada Enriquez, M. (2010, March). *Teachers' approaches to implementing a problem-based learning simulation.* Paper presented at the Society for Information Technology & Teacher Education International Conference, San Diego, CA.

Goldman, S.R., Braasch, J.L., Gepstein, R., Brodowinska, Kamila, Wiley, J. & Graesser, A.C. (2004, Aug.). *Doing Research on the web: Comprehending complex science information.* Paper presented at the Society for Text and Discourse Conference, Chicago, IL.

Oney, B., Goldman, S. R., Lauterbach, M., Braasch, J., Kusumgar, R., Brodowinska, K. & Golden, R. (2003, April). *Assessing complex comprehension through computer based and paper and pencil testing*. Paper presented at the American Educational Research Association, Chicago, IL.

RESEARCH EXPERIENCE

2008 – 2018 *Expanding the Science and Literacy Curricular Space: The GlobalEd 2 Project*
College of Education, University of Illinois at Chicago

2013 – 2015 *READi: Reading, Evidence, and Argumentation in Disciplinary Instruction*
Learning Sciences Research Institute (LSRI), University of Illinois at Chicago

2002 – 2008 *Teaching Teachers to Use Technology: What Works and Why*
Understanding in Science
Reading Comprehension and Assessment
The Center for the Study of Learning, Instruction, & Teacher Development (LITD), University of Illinois at Chicago

TEACHING EXPERIENCE

2012 – 2013 *Instructor - Faculty Assistance Center for Technology (FACT)*
College of Education, University of Illinois at Chicago

Summer 2008 *Workshop Instructor - Teachers Infusing Technology in Urban Schools Project (TITUS)*
College of Education, University of Illinois at Chicago

SERVICE TO PROFESSION

2010 *Manuscript reviewer*
Journal of Educational Computing Research, JECR

2009 *Proposal reviewer*
American Educational Research Association (AERA)

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