Project-Based Learning: Theory, Impact, and Effective Implementation

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This paper reviews the literature on the teaching methodology of project-based learning (PBL), covering its characteristics, inception, and the results from implementation. From the existing research, PBL is found to be an effective instructional paradigm compared to traditional teaching methods. A collection of issues for effective implementation of PBL is constructed bearing in mind both what is best for creating educated and formal reasoning citizens and what should be done to avoid PBL from degenerating into less effective paradigms. Several tests are suggested for investigating the qualities of a given implementation of PBL, notably in the context of physics.

I. INTRODUCTION

"I hear and I forget. I see and I remember.
I do and I understand." – Confucius c. 500 BCE

In the effort to better educate students for future careers as well as becoming generally knowledgeable citizens, more and more research is being conducted to determine what methods are best for instruction. The question of what makes effective teaching can and should be approached both broadly, as in what instructional paradigm is to be used, and specifically, as in what things should be done in the classroom given the paradigm. Here one particular methodology will be examined, project-based learning (PBL), along with how it can be as competent a tool as possible. What it is and how it compares with prior teaching pedagogies will be explored, as well as the data that supports its effectiveness compared to traditional methods. A history of the approach will be reviewed as is instructional to what can affect the implementation of PBL. Next, a collection of issues in creating the effective performance of PBL are detailed as well as the evidence supporting these positions. Finally, ways of testing an implementation of PBL are suggested, investigating both its effectiveness in teaching and its stability as a tool used by instructors.

II. TEACHING GOALS, PBL CHARACTERISTICS, AND HISTORY

The features, goals, and history of project-based learning and education in general are strongly tied together, especially in the minds of educational reformers in the early to mid-twentieth century. In part the history is a matter of necessity and changing social circumstances, along with developments in the science of psychology. In the United States at the turn of the century, elementary schools were becoming common and compulsory as they saw the need to invest in a future work force that was competitive (Graham, 1974). States would model themselves upon European forms, notably the Prussian system, which itself had much in common with teaching modalities from centuries before. These methods tended to follow a lecture-and-examine structure, imparting knowledge upon students as absorbable facts. Knowledge is transferred from teacher to student; the common metaphor is children are 'blank slates' on which the teacher inscribes knowledge (cf. Locke, 1690). The modern version of traditional methods comes under the umbrella of direct instruction (cf. Engelmann, 2007).

However, this idea of knowledge and how it is generated had become strained with the work of psychologists and philosophers. This can be seen particularly in the works of the American philosopher and reformer John Dewey and the Swiss developmental psychologist Jean Piaget (cf. Dewey, 1902; Piaget, 1963). In their understanding of epistemology, knowledge is generated through experience, connecting notions they encounter, such as in a classroom context, with the concrete. This was a step-wise process rather than a binary learned task, and the process itself creates beliefs that may be later discarded. Piaget, who studied child development, argued young pupils will create mental constructs that they can dismantle at a later time should they discover that they do not function well in new contexts. Children, seen normally as having adult minds but lacking the needed information for maturity, were now understood to think differently than adults. This meant that knowledge and understanding come through discovery rather than repetition of facts (Piaget, 1973). This paradigm of learning as discovery and creating meaningful models through the interaction of experience and ideas is labeled constructivism.

In the new paradigm, the primary goal of education still remained: providing pupils with the facts and methods needed to be functioning citizens, and students retaining these important facets. However, with the increasing amount of schooling that students were beginning to receive at the turn of the century meant there was more to education that the basics of reading and arithmetic. With a more complex labor sector, and even more so in the twenty-first century (Bell, 2010), this meant a greater need for deep knowledge and transfer skills. Deep knowledge means that a subject matter is understood at a more fundamental level, providing notions that are more generalizable. The ability to transfer knowledge to another domain not directly taught in the classroom is also an asset finding greater demand in the more intricate world. This made constructivist thoughts even more relevant with its understanding of how knowledge is grown.

How best to grow this knowledge was also under consideration of reformers such as Dewey. Emphasis was laid on the process of inquiry, investigations as done on the part of the student rather than the instructor. Moreover, inquiry-based learning founded itself on having questions rather than answers, and the questions could be more open-ended than what is asked in a multiple choice test, for example. The process of inquiry, as argued by Dewey, needed to be done not in isolation but with students interacting with each other and the instructor. This way ideas would be discussed and examined by several minds and if need be guided by the teacher. Dewey also saw the inquiry process with team effort as fostering democracy and its values (Johnston, 2006).

The constructivist paradigm thus has the teaching goals of long-term retention, deep understanding, knowledge transfer, inquiry skills, and teamwork skills. Several ways exist of putting constructivist philosophy into action, such as discovery learning, active learning, and project-based learning. Here we focus on the latter and its defining traits.

The project method of instruction has a long history, plausibly pushed into the pre-industrial era (Knoll, 1997), but the method with stronger philosophical and psychological backing, along with wide dissemination in public schools, is more recent and pertinent. Two features of the inquiry process utilized in PBL include an ill-defined problem and a student-centered learning environment. The ill-defined problem is crafted in such a way that it is not clear either what the answer would be or how to solve it. The problem is often open-ended as well such that it can be a continuous question of future experiment and research. To create a solution to the problem, students will consider multiple possible pathways, and through their attempts and inter-student dialogs they will work out possible resolutions. This leads to the students acting more as their own instructors, determining what they need to know rather than a teacher furnishing needed information.

In the process, students are likely to have ideas fail or their prior notions conflict with the reality they encounter when completing a project. This will put the students in cognitive conflict, and resolving that conflict will induce learning. Instructors are to provide coaching to the students to encourage them to overcome their difficulties and provide advice. More on coaching will be discussed in the implementation section below.

The student-centered method also means that pupils will work in groups rather than as individuals. In this way not only are tasks delegated for the completion of necessary tasks, but possible solutions are discussed and debated. In this way ideas have to undergo the scrutiny of several minds and sets of experiences rather than one, along with the battery of tests via the experimental method. Small group work is often a part of inquiry-based learning and is central to PBL. Group inquiries into ill-defined problems are ultimately geared towards providing deep understanding and long-term retention of the knowledge needed in completing the project.

While the above characteristics are common amongst constructivist teaching methods, a few characteristics distinguish PBL. One important feature is the use of instructor scaffolding. This is where the instructor provides support to the students at stages to help them build up their knowledge; as the students are better able to handle tasks or demonstrates knowledge the instructor provides less scaffolding, much like in the construction of a building. Scaffolding differs from traditional teaching in that the instructor does not simply provide information, at least not directly, but uses prompts and other tools to help students answer their own questions. This feature also distinguishes PBL from the teaching method of discovery learning which implements little to no scaffolding, let alone direction instruction.

The final key feature to PBL is its namesake, the project itself. PBL curricula are designed to have a final product, an artifact produced by the students which give the students their end goal and something concrete to make their knowledge applicable; this induces reflection on their experience in creating the project and the ideas they have in accomplishing their goals. The artifact functions as a way for the newly constructed knowledge by the student to be grounded and useful to the learner, motivating the pupil more than traditional methods tend to. This can be compared to problem-based learning, which unfortunately has the same acronym. Both methods are similar, even more so than between PBL and discovery learning, but the defining feature that distinguishes the two is that project-based learning has a final result of some artifact created by the students. Since both types of methods are pedagogically similar, including the utilization of scaffolding techniques, the results of either method can be reasonably compared; where one type of approach is more appropriate than another one should considered on a case-by-case basis, but this will not be discussed here.

While the above does well to characterize the aspects and goals of PBL, the literature shows that other educations include additional goals. They are not so well delineated, so it becomes harder to examine for PBL's effectiveness in achieving those aims. For example Helle et al. (2006) in a meta-analysis of post-secondary education implementations of PBL often found the stated goal of increasing communication skills. As noted by the authors, this is a rather broad skill set rather than a specific ability. When goals are loosely understood, this makes assessment difficult in an objective manner. This may be partially the reason that the implementers of PBL in post-secondary education far more often than not only gave anecdotal information concerning improvements in students' ability. While anecdotes may help indicate areas where new or further research may be worth considering, it does not help in discovering the reality of the effect, let alone comparing it to non-PBL methodologies.

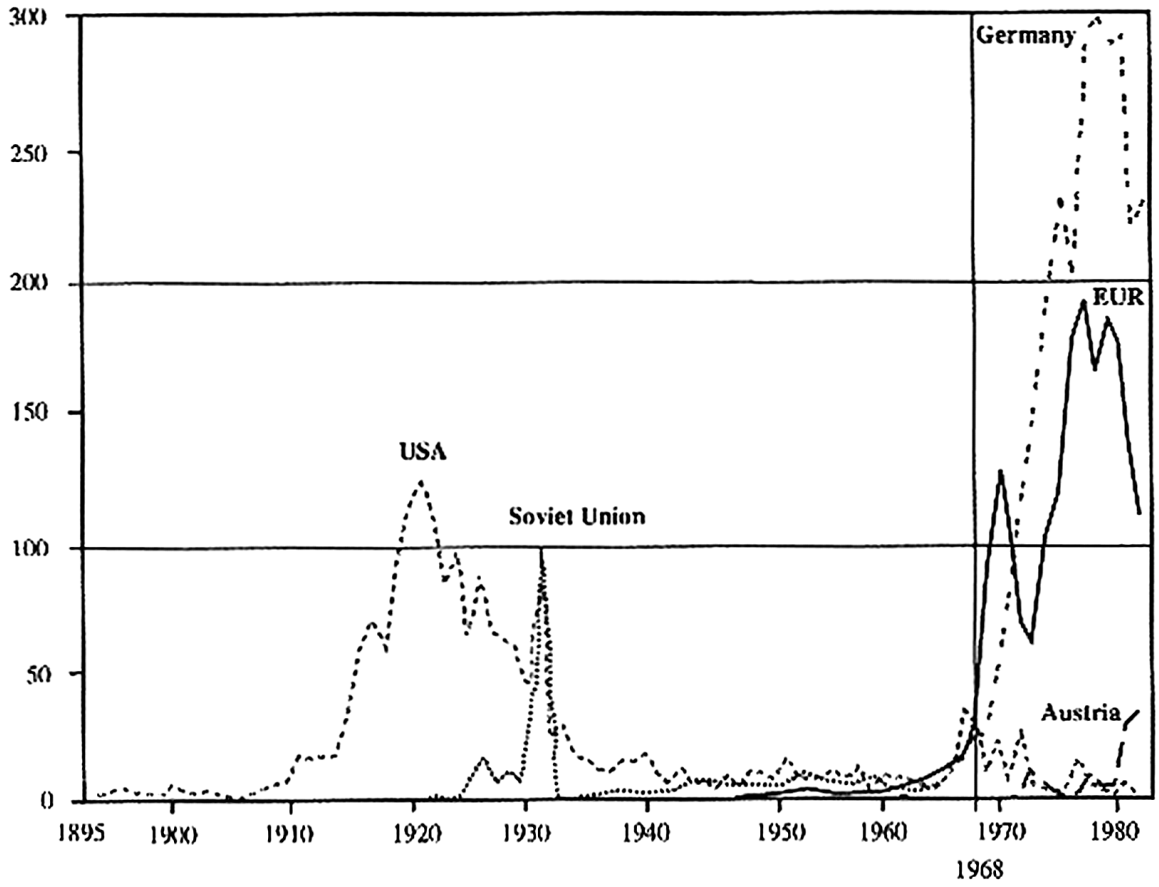

Figure 1. Number of Papers Published on Project Learning from 1895 to 1982. EUR = Belgium, Denmark, Great Britain, Netherlands, Norway, Sweden, Switzerland. Graph reproduced under permission from Knoll (1997), adapted from Petri (1991).

A similar issue may also exist with the goal of fostering critical thinking through PBL, another commonly-sited goal amongst educators. There seems to be overlaps with the goal of increasing a student's ability to apply learned knowledge and the goal of critical thinking. Without a clear differentiation between these two subjects it becomes difficult to assess if critical thinking skills have in fact improved. This is especially necessary when PBL teachers implement ill-defined problems such that student knowledge needs to be functional, and critical evaluation of the situation identified by the instructor is necessary for the application of such knowledge. Perhaps a better way to define and then test such abilities is to consider critical thinking as identifying flaws in thinking or information. This would then differentiate between applying knowledge to some concrete goal (i.e., building a bridge) and critical thinking about some issue (i.e., a Socratic approach; assessing quality of data sources). Assessment could then be either to give a problem to students in which there is some flaw in the information or logic, or some assumption of the students is identified and then scrutinized by the students – this would be comparable to the cognitive conflict method of teaching (Limón, 2001).

The discussion at this point has talked about developments at the beginning and middle of the twentieth century, especially tied with the Progressive movement of these times. However, PBL and constructivist teaching modalities are not a universal in modern education in the industrialized world. This leads to the question of how much the technique has been tried in the past, its success in its educational goals, and how well it remained part of standard curriculum. In connection to the goals of PBL, this teaching paradigm needs to have the objective of continuous utility; the methodology needs to be sustainable to be effective. While the following section will explore the evidence for the effectiveness of PBL, it is worthwhile to consider the history of implementing this teaching pedagogy and how well it became standardized as it reflects on the complexity of enacting new methods like PBL.

Efforts to implement PBL or something similar can be traced back to the French philosopher Jean-Jacques Rousseau (1762), though the emphasis of group learning or a community of learners does not exist. More important was the influential psychologist, philosopher, and educational reformer John Dewey at the turn of the century (cf. Dewey, 1902). He emphasized the active features of the learning

Table 1. Comparison of Teaching Pedagogical Foundations, Goals, and Features

	Teaching Method			
	Traditional / Lecture-Based Instruction	Project-Based Learning	Problem-Based Learning	Discovery Learning
Foundation	Direct/Guided Instruction (Engelmann)	Constructivism (Piaget); Inquiry-based	Constructivism (Piaget); Inquiry-based	Constructivism (Piaget); Inquiry-based
Educational Goals	Information retention, short and long term	Deep knowledge; long-term retention; knowledge transfer; inquiry; team-work skills	Deep knowledge; long-term retention; knowledge transfer; inquiry; team-work skills	Deep knowledge; long-term retention; knowledge transfer; inquiry; team-work skills
Features / Method	Top-down instruction; teacher-centered; lecture & rote memorization; less hands-on activity	Student-centered; group work; ill-defined question; scaffolding; final artifact; cognitive conflict & resolution; coaching	Student-centered; group work; ill-defined question; scaffolding; cognitive conflict & resolution; coaching	Student-centered; ill-defined question; little to no instructor scaffolding; cognitive conflict & resolution; coaching

process and breaking the mold of the teacher proclaiming facts for the student to inherit. Learning was to be a more democratic process, a point expressed clearly by Dewey. Especially influential in giving a psychological framework was Jean Piaget with his efforts in reforming education, but even before him schools in Europe and America had made similar PBL practices a part of the curriculum. Where PBL was executed, results were positive in both performance and satisfaction (see Aikin, 1942; Cremin, 1961; Cole & Griffin, 1987), providing reason to believe in the effectiveness in the general idea being promoted by the reformers.

In addition to the work of Dewey and Piaget around the same time, the concept of "zone of proximal development" from the Soviet psychologist Lev Zygotsky helped express the utility of the instructor in scaffolding – a teacher can increase the zone of what is understandable to a learner (Zygotsky, 1978). Another American reformer and colleague of Dewey, William Kilpatrick, was also influential in the development and broadcasting of the project method. However, Kilpatrick and Dewey differed on the need for teamwork as opposed to individual learning and the utility of the instructor (Kilpatrick, 1918; 1927; Dewey, 1933; 1938). While the details of the project method were debatable during this time, there were signs of success in implementing PBL and achieving its results.

Even so, PBL apparently died out by the 1960s in the United States after the influence of the progressives had weakened (Knoll, 1997), Dewey himself being caught up in the Red Scare of the 1950s and the FBI creating a file on him during Senator Joseph McCarthy's tenure in Congress (Westbrook, 1993). The Soviet Union also had done substantial research in PBL, promoted even by the Lenin's wife and fellow revolutionary, Nadezhda Krupskaya. However, it was stifled by the Central Committee under Joseph Stalin in 1931 and never recovered during the Communist Era since it was believed to not teach skills for industrialization and not increase communist consciousness; this restriction also applied to the communist European states after World War II (Knoll, 1997; Holmes, 1991). In contrast, Western Europe continued to do considerable research on the subject matter of PBL without similar political molestations, especially in democratic Germany (see Figure 1). In the post-war period, Western European schools have become more like the American ideal of Dewey, while American schools have become more like the traditional European format. There were several factors that led to the degeneration of PBL including teachers that had instructional philosophies at variance with constructivist approaches, the social environment of student-student and student-teacher interaction, and outside socio-political forces (i.e., economic and political). The issues that had these negative effects on PBL will be discussed in the implementation section below so that such pitfalls can be identified and potentially avoided. Nonetheless, PBL has become more widely implemented and researched in the Americas in recent decades (Polman, 2000; Clark, 2006; Katz, 1994; Katz & Chard, 2000), perhaps in part because of the standing of U.S. students compared to other first-world and industrializing nations.

While history has provided certain hazards for PBL, the features of this teaching methodology, simplified and compared to others in Table 1, have nonetheless been used around the world and over the last century in meeting its educational goals. The use of the project in conjunction with inquiry-based group activities and instructional scaffolding makes PBL unique amongst the various pedagogies, and its utility will be addressed in the next section, while its historical legacy will be understood better when considering what socio-political forces affect its enactment in the effective implementation section below.

III. RESEARCH ON EFFICACY OF PBL ON STUDENT LEARNING

The primary goal of this section is to see what examinations have been done to see how effective PBL is in achieving the goals of knowledge retention, procedural abilities, knowledge transfer, and teamwork skills. Several useful evaluations have been done that measure both the ability of students in PBL as well as students not in a PBL curriculum. Such investigations have also been done in various subject matters, and a few will be highlighted here as exemplars for PBL evaluations, concentrating on science and math courses, along with meta-analyses of this educational method. We find that examinations of information recall are numerous and their assessments quantitative and positive; the case is similar for transfer skills, though results are not as numerous. Tests of workforce preparedness and teamwork skills were primarily surveys with mixed utility.

As a first example of these evaluations, we consider a three-year study in Britain of math students. Students who had the same instructional background and similar abilities went to schools using and not using the project method for three years were compared using a number of tools, including student interviews, questionnaires, assessment tests, as well as the national math exams in Great Britain. The researchers found that when compared to traditionally taught classes, PBL students were much more likely to receive the highest possible score in the national exam by a factor of three. In written questions soon after finishing work, both groups of students were equally capable in the particular math ability they had been working on, but after time those that had been in traditional schools were not as able to recall information as well as the project school students. There were also more limitations on the ability of traditionally taught students to apply their knowledge to new contexts, especially real-world situations. These limitations seem to also cause students to think mathematical principles are a matter of memorization, an attitude less prominent among PBL students (64% vs. 35%). Concerning procedural questions, PBL students were equally capable as traditional students in this area, but the former were superior at applied and conceptual problems (Boaler, 1999). Such a study indicates that PBL was successful in helping students integrate mathematical knowledge into a broader context rather than isolated facts and procedures, thus PBL completed three primary goals: long-term knowledge retention, depth of knowledge, and transfer skills to real-world scenarios.

This pattern of approximately equal ability in retaining information and a notable increase of application ability with PBL are found in other studies. An analysis of three activity-based science programs for elementary students used several tests, including logical development tests, found an increase in ‘inquiry skills’ and a small increase in retention of subject material, though these results were more mixed (Bredderman, 1983).

Reading skills also see appreciable gains with the implementation of PBL. For example, Iowa three schools, all of which were well below the state average before enactment of PBL, implemented a project curriculum called Expeditionary Learning. By the end of two years, two schools met the state average and one went beyond in the standardized Iowa Test of Basic Skills. While the state’s averages remained constant, these schools saw gains from 15% to over 90%, and four years later graduates of these schools performed above the district average in most subjects (Thomas, 2000). This demonstrates not only deep reading knowledge but significant transfer skills as well since most all subjects were improved by implementing PBL. Similarly impressive results are noted by Thomas (2000) in other school systems.

A meta-analysis of 39 studies concerning undergraduates in science, technology, engineering, and mathematics (STEM) is particularly instructive to physics education. This study drew from a large collection of results from various implementations of small-group learning, which was itself very diverse though often including open-ended projects. This meta-analysis is superior to others in that it also used unpublished results to see if there as a publication bias towards positive achievement results. It was found that there was not an achievement publication bias though there was a bias for positive attitude reports. Measures of achievement include standardized tests and final grades for classes. The meta-analysis found that cooperative or collaborative learning methodologies showed a substantial Cohen effect size of about half a standard deviation ($d = 0.51$) in improved scores compared to traditionally-taught student scores (Springer et al., 1999). This demonstrates well that projects in small groups are substantially better than standard teaching methods when it comes to achievement.

A study using the pedagogically similar problem-based learning approach with medical students found that measures of knowledge was about the same for students using traditional methods, but had a measurable increase in diagnostic ability (Albanese & Mitchell, 1993; Colliver, 2000; Dochy et al., 2003; Vernon & Blake, 1993). Also of interest is that these medical students, even if they had not done as well as traditionally-taught students in memorization of factual information, they were more likely to have remembered the information they retained for the examinations at a later date. Clearly then, PBL is quite capable of fulfilling its goal of improving scores in information-content examinations.

Another observation of these studies is that the PBL approach is able to help students at all levels of ability. For example, a project in designing chairs for sixth graders found an increase of 10% in a standardized geometry test and found it equally effective for lower achieving students as it was for average and high achieving students (Barron et

Table 2. Comparison of Teaching Methods. Relative scale from weak to strong as compared to other methods. Comparison helped by Mayer (2004); Kirschner et al. (2006); Hmelo-Silver et al. (2007); Strobel & van Barneveld (2009). Results for discovery learning are not as clear in comparison as PBL to traditional methods. This is in part because the amount or existence of instructor scaffolding is not constant in published examinations of the methodology.

Teaching Method / Abilities	Traditional/Lecture-Based Learning	Project-Based Learning	Discovery Learning
Short-Term Knowledge Retention	Strong	Moderate	Weak
Long-Term Knowledge Retention	Weak	Strong	Moderate
Depth of Knowledge	Weak	Strong	Moderate/Strong
Transfer Skills	Weak	Strong	Moderate/Strong
Inquiry Skills	Weak	Strong	Moderate/Strong
Teamwork Skills	Weak	Strong	Moderate/Strong

al., 1998). The STEM meta-analysis mentioned above also found that small group learning was particularly helpful to under-represented groups in the field, namely African-Americans and women (Springer et al., 1999). As such, the data indicates that implementation of PBL is appropriate for a wide variety of subject matter and students and is effective in achieving the goal of creating deep knowledge for all rather than the fortunate.

The positive benefits of PBL were not limited to knowledge retention and application, but other aspects as well. Since education must ultimately prepare students for work later in life, a comparison of methodologies is also useful to see how well students fair once they enter the work force, the final assessment for transfer of taught skills and knowledge. For engineering professionals that had gone through PBL at university level, surveys found that these former students felt better prepared in theoretical knowledge and application but weaker in handbook knowledge (Kjersdam, 1994). This means the PBL pedagogy is useful in preparing qualified workers with what they feel is a more adequate capacity to think about problems than traditional methods would, and this is the very thing desired of the future work-force. This study further indicated that these former students were better prepared in their first job, and their employment was stable; in their first 3-4 years in the workforce, less than 1% changed their job because of feelings of inadequacy while 13% changed due to feeling unchallenged at their place of work. About half of those evaluated said that the source of their professional knowledge came from project work. However, this study had no contrast with engineers from universities that did not implement PBL techniques, so the survey results of former students are harder to assess without this comparison. Nonetheless, the broad feeling of competency is substantial in its own right.

Along with individual competency is teamwork competency, and PBL should be particularly helpful here because a significant portion of project work is group effort. The literature on this point is not great, perhaps in part because of the difficulty in measuring teamwork skills. As an example of the effectiveness of PBL to improve this social ability, a Danish study using survey questions found that students in a university implementing PBL more highly valued teamwork than those in a traditional class format (Fink, 1999). Such a subjective measure is useful since a greater appreciation for teamwork should translate into improving those very skills, but it leaves more objective measures to be desired. However, this same study showed that students in PBL environments were more willing to work with people of different educational and cultural backgrounds, which is certainly a desirable result in both business and social settings.

All of the above studies, and most others, compare PBL to the traditional methods of teaching, but this is not the only competing pedagogy with the project method. Along with the above considerations of PBL, this strategy of teaching should be contrasted with other student-centered methods where there is little or no guidance from the instructor. Critics of constructivism have tried to show that unguided inquiry on the part of students is not effective in learning (Mayer, 2004; Kirschner et al., 2006). However, a major

point of PBL is the metaphor of scaffolding, in which the instructor lends support to students to help them go beyond their current limitations as well as provide checkpoints to assess student progress; the use of computer problems built for PBL implementation also acts as scaffolding as it can produce a learning environment within defined limits to push the student into investigating the material effectively. With this in mind, PBL, as differentiated from discovery learning and similar pedagogies by its use of instructor guidance, is then shown to be effective (Hmelo-Silver et al., 2007), and a similar result can be seen in active learning approaches though the mechanisms are not so well understood (Michael, 2006). This key difference avoids the more potent criticisms against the constructivist paradigm while also demonstrating that effective teaching must lie between the old method of filling the heads of children with knowledge by lecture and tests and free roaming of students without guidance. Where exactly in that spectrum the optimum point lays may be task or time dependent; this can only be determined through further investigation.

Overall then, research indicates that, comparing to traditional instruction, this student-centered teaching methodology is better able to help students in the integration and contextualization of knowledge, which is further supported by the meta-synthesis aggregation of meta-analyses making the same point of PBL effectiveness in long-term retention of knowledge, though in the short term and for questions reliant on rote memorization traditional methods were more effective (Strobel & van Barneveld, 2009). That students more readily develop deep knowledge is demonstrated by various studies, so a different and more effective sort of learning it taking place. Those that go through PBL programs feel better about working in teams as well as more prepared for the workforce. Other goals are not so well defined and should either be clarified or not attempted as too many goals will undercut successfully fulfilling those very ambitions (Helle et al., 2006). Nonetheless, PBL is able to perform better than other teaching methods in the areas that matter most to education, and an increase in its implementation becomes warranted due to these results seen in various subjects evaluated around the world. How to make this happen is the subject of the next section.

IV. EFFECTIVE IMPLEMENTATION OF PBL

In this section we provide a number of points to consider for the successful implementation of PBL, largely bolstered by Polman (2000) in his case study along with other analyses. This section will first break down the conditions or elements that make PBL more or less effective into three larger categories, namely the curriculum, the teaching-learning environment, and the administration. These first two categories are summarized in Figure 2. All these categories will focus on not only what makes PBL effective, but what will allow it to not degenerate into older teaching paradigms. The considerations for effective PBL are summarized in Table 3.

First is the curriculum, a core component that frames what is planned for teaching and how best to set up problems for students to solve. This will examine details such as what sorts of scaffolding devices are useful – worksheets, websites, computer programs, etc. Emphasis is laid on the process of making an effective syllabus.

Second is the teaching/learning environment – what happens in the classroom and outside as well. Student-student and student-teacher interactions will be considered, along with the general environment created by the dynamic social arrangement in the school as well as outside. Techniques for interacting with students, when to do so, and how to encourage maximal learning are addressed.

Third are administrative issues, for emergent difficulties may come from above in the educational hierarchy and even force teachers into more lecture-based education. Economic and political forces are cited, but ways to avoid these problems are not addressed as they are beyond the scope of this paper.

A. Curriculum

Creating an educational program for students starts with what a project should encompass. This is usually dictated by the course in question. An earth science course will have projects concerning subjects such as geology, climate, etc., while social studies will have other avenues to pursue. Another dictate from the nature of the course is the length of time given to a project. If a school term is ten weeks, a PBL course should be done in that time. Depending on what things are required of the teacher, a project may be much shorter, perhaps a week or two. These temporal considerations are forced largely through administrative regulations, which will be considered later.

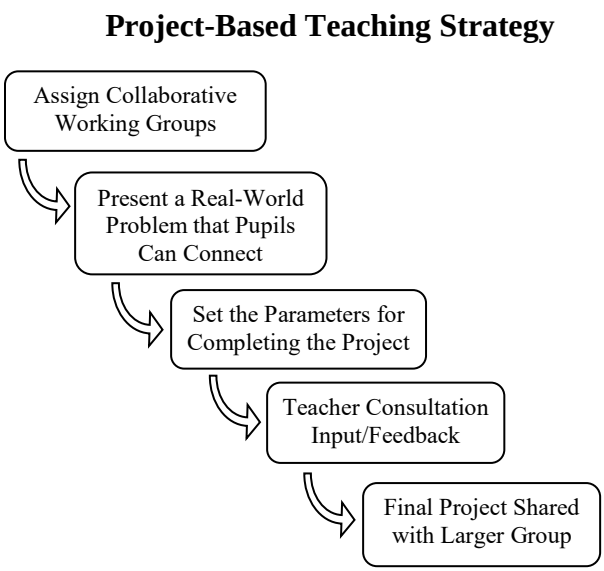

Figure 2. Project-Based Teaching Strategy

More directly controllable for an instructor is the syllabus. In particular, it is necessary to lay out a schedule for not just the due date of the final project, but goal posts or milestones along the way are also useful. If students have a large period of time before the completion date of their project, they may delay their work. Moreover, by having goals along the way the instructor can determine where students may be having difficulty. Having to wait until the end before discovering that a student or group has not correctly understood their tasks will certainly lead to frustration and undercut the utility of PBL. Such goal posts act as scaffolding as well as a force for students to complete some aspect of their work while the instructor can provide help. This is advantageous compared to discovery learning. Further consideration of goal posts will take place below.

A second aspect of the syllabus is to try and clarify a number of points in advance. PBL uses ill-formed problems for students to try and solve, and because of the purposeful ill-forming of questions it leads to anxiety. Fears of what will constitute a good grade will make progress difficult and cause students to request instruction to such a degree that it may cause degeneration into traditional instruction methods. Teachers should then do what they can to initially tell students what to expect, especially since PBL will be new to students and run contrary to their expectations. A grading scheme in advance can help alleviate anxieties; if students know what is expected of them, they will feel like they are taking fewer risks and will be more focused on doing their project and hence learning. Unless students take epistemic risks they are neither likely to expand their knowledge base nor integrate the knowledge both old and new, nor will they be as willing to apply critical thinking to their problem. However, because of the purposeful ill-formation of the project questions, such anxieties cannot be completely circumvented (Suchman, 1987). An instructor should expect to see many procedural questions during the term (Polman, 2000). One may likely be asked more about procedure than the subject matter any project is related to.

A point that instructors should be wary of is that students will likely take a very strict reading of the assigned and graded duties a project will involve, meaning that they will feel their obligations exist in a literal reading of the syllabus and may not realize that they need to do more than the letter of the page specifies. Often when students received a poor grade on some aspect of their work they will point to the syllabus and say how they had done the specified tasks, even if in a superficial manner. One way to alleviate this anxiety is to indicate that the grading criteria are not absolutes, and the opportunity to turn in a corrected version of an assignment should be allowed for credit. This will not solve all potential problems, but it can mitigate the issue as much as possible when considering the ill-defined nature of PBL assignments and the limitations of any syllabus or written document.

A well-structured syllabus should also try to spread out the workload of a project. Students usually perceive that PBL assignments are very time-consuming, but this may be more the product of students remembering the peaks of time consumption in doing their work and remembering less fully the lulls in their workload. To combat this perception, the best strategy is to create a schedule that helps even out how much work needs to be done in a particular amount of time (Helle et al., 2006). Moreover, if the students are effectively "cramming" before a major due date they will have less time for reflection and will be too stressed to think deeply about their project.

One aspect of the syllabus schedule that will be discussed more below is the milestones or goal posts set by the instructor for certain tasks to be done other than the final deadline for the project; this becomes especially important if project timelines are over several weeks or months. Clear dates for particular aspects of a project should be given along with what is expected for credit. The experience of one PBL implementation recounted by Polman (2000) shows that these goal posts should be given a considerable amount of weight in the final grade so that students take these deadlines seriously. Without such deadlines, it removes time the instructor has for feedback, conversations with students, and needed scaffolding.

Besides the syllabus and the general subject matter dictated by the school, the more specific aspects of what a project should be for students will have several considerations. The scope of the projects should be neither too broad to be undoable in the allotted time nor too narrow to be technical or dreary. Related is the difficulty of a project – the task should be something within the limits of what the students of a given skill level of capable of, yet it should provide a challenge. The projects should also be interesting to the students, or else they will not attempt to learn as much as they would otherwise. These are all judgment calls that are difficult to make in an objective manner but can be refined with experience. Moreover, careful observation early on can detect if a project is capturing student interest, is doable in the time frame, and is sufficiently challenging (Helle et al., 2006).

With a set syllabus and the projects arranged early in the course, the designed curriculum must also have a planned way of providing scaffolding, the tailored help provided by the instructor to the learner. Effective scaffolding must do more than solve an immediate problem for students, but instead it must prompt the students into figuring out how to solve the problem themselves. This is a key aspect to constructivist teaching pedagogy, so an instructor must consider what input the students receive such that they are being helped rather than told what to do.

There are several considerations in producing beneficial scaffolding. First is that the instructor should set boundaries on what activities students will do, such as breaking down tasks into manageable pieces in order to complete complex tasks, or the instructor can indicate what research sources they should try; with an infinite space of activities a student could do, this will likely become unproductive without guidance. This may include limiting the parameter space in computer software or what books or websites are more useful for laboring on a project. Second is that instructors should make clear the rationale for doing these projects to

keep students' interests in the subject and so better engage them in studying the material. Third is that any routine tasks for completing a project should be handled in the scaffolding to make time for deeper inquiries the students will have. For example, the instructor may help a student unfamiliar with a word processor make tables, a task likely to be repeated by the student but requiring input from the proficient teacher. Fourth is that there needs to be reflection regarding the work done by pupils, especially for those that normally avoid such introspection. This will include helping the pupil in articulating the subject matter, which can be done through verbal prompting by the teacher or through general discussion (Quintana et al., 2006). More on scaffolding will be discussed in the next section.

This fourth point, when focused on instructional material, leads to another concern from a historical perspective. When new technologies came into vogue in classrooms such as films, they were simply integrated into the old teaching paradigms (Polman, 2000); the structure was the same, just the delivery of information came from another source. Moreover, if teachers are also caught in the mindset not amenable to PBL but to older instructional methods, it is likely that PBL will degenerate back into standard lecture-based teaching. To avoid these sorts of pitfalls the instructor must be conscious of what their own thoughts on teaching are and how they want to introduce material to their students. Lesson plans need to avoid chalkboard-based teaching in favor of active participation amongst all parties.

B. Environment

This section will consider two environments, that created in the classroom and that outside, with emphasis on the former since this is something an instructor has more control over. In the classroom, a teacher has to provide guidance to pupils without being too instructive. Because of the number of students or groups, time is a resource that must be managed. Instructors also need to make amenable their interactions with students as well as keeping a level of order between students.

First is the consideration of time, which is "the determining factor in the organization and structuring of tasks" (Ball et al., 1984). PBL assignments are very time-consuming for students as well as instructors, so how it is doled out is a primary aspect of what can make PBL effective. Time allocation is also one of the most reported problems in implementing PBL (Helle et al., 2006). One aspect that makes time management difficult is its perception. Given a significant amount of time to complete a project confers the feeling that there is plenty of it to do what is needed. This psychological predisposition can be managed by intermediate goal posts as described before as this will make deadlines more immediate.

A teacher's time is also limited, a resource that is significantly taxed when implementing traditional methods let alone PBL (Scott, 1994). Students desire feedback and as soon as possible, especially with looming due dates, so an instructor often feels the need to return graded work quickly yet with notes to students that can be helpful. One way to relieve this strain is making project aspects due close to the end of a work week, allowing the teacher to examine assignments over the weekend (given that Saturdays and Sundays are free). However, the most pressing times are during class periods when the issues students bring up are numerous, and now there is a much more restricted timeframe to help students. It is also difficult to know what problems are the most pressing in advance and how to perform some sort of triage. Should the teacher help one group that can't find where they had just saved some document on the computer or the group having difficulty with a conceptual issue in their chosen endeavor? It is usually impossible to know what could be an issue and how long it may take to help alleviate those problems. There is also the issue of whether it is best for the instructor to be proactive or reactive, whether to come up to groups and prod those students with inquiries or to wait until they have a question.

In a case study by Polman (2000), usually the temporal state of affairs was managed best when it was the students that initiated a request for help with their subject. However, the instructor should not remain distant until called, especially with groups that show signs of falling behind. Groups that ask few questions may feel so lost that they are afraid to ask, and it becomes the duty of the teacher to break this divide. Concerning questions asked by students, it will appear to them that their issue is pressing, even dire, no matter what it may be (i.e., a missing downloaded file). Also, many if not most of these inquiries will concern procedure or what is needed to get a superior grade. Before it was advised to specify as best as possible grading criteria in the syllabus, but these sorts of questions are likely to persist. However, it is best to answer other questions, so an instructor should inform their pupils that he/she wants to avoid procedural/assessment questions in their limited classroom time.

The purpose of the teacher/student interaction should be to induce reflection, the hallmark purpose of PBL and the generative force behind deep learning. This is why it is important for the instructor to be proactive in minimizing procedural and assessment questions to maximize time for subject-matter questions. Polman's (2000) case study again showed that groups that asked more science questions rather than procedural inquiries performed better overall. This probably reflects that inquiring students were putting in the most effort when encountering their subject and coming into new information with which they were not familiar.

Time issues aside, the environment of the classroom must also be made as congenial as possible to make PBL feasible and useful. The social environment created by the students is one that an instructor can have some control over, and this becomes important if groups start not to work well together. For the process of forming groups, an instructor should try to pair up students of differing academic prowess, avoiding the creation of groups lacking in leadership, ability, or intellectual drive that will likely spiral into failure. This means that students should not decide their groups, at least not exclusively. Interactions between students and teachers can also become antagonistic with the student able to grind progress to a halt should they feel so frustrated (Lemke,

1990). Students are likely to feel frustrated not only if they are not performing very well, but if they had previously been used to high marks in traditional teaching environments. The feeling of being adrift greatly increases anxiety and makes work all the more difficult.

To help with group problems, it is often advised to have confidential meetings between a student and the instructor. Here the pupils can express themselves regarding what is causing them angst while not feeling the social pressures from other students not to make a fuss, especially in the presence of the potential group member who is causing the problem. Such confidential discussions are also useful to see the progress of a group both as a whole and for its particular members; this can help identify problematic groups early and arrive at a resolution sooner, thus allotting more time for useful endeavors. Along with meetings to see if some students are not pulling their own weight in completing their tasks, another possible motivating force could be for the students to assess themselves; if one member of the group is seen by others to be unhelpful, they can be downgraded. This way the instructor can have individual grades for students as well as incentive for all members to help.

Concerning adversarial interactions between instructor and pupil, this can be mediated by creating common ground between the two parties (Rogoff, 1990). The guided participation that is formed in student/teacher interactions relies on "intersubjectivity" between these participants. Intersubjectivity is the prior agreed understanding between subjects, similar to 'common sense' – the common understanding of matters. Teachers and students need to have some common ground in order to effectively communicate, but it is the differences that necessitate communication. Teachers will challenge the perceptions of their students, but they should not lose all points of contact. A loss of intersubjectivity can happen in PBL because teacher and student expectations become divergent, which can in turn lead to hostility. Perhaps one way to help repair such relationships is to explain the goals and objectives of PBL and to make the project interesting to the students again. This would also require uncovering the student's interests which may become difficult if the relationship has greatly deteriorated. Moreover, the instructor should retain a respectful tone even if the student has become furious, since further antagonism is unlikely to be fruitful.

Assuming that time is manageable and social friction is kept at a minimum, there is the ever-present need to keep students wanting to apply themselves to their task. Besides just procrastination, students may try to do as little as possible to get a passing grade. One way to mitigate this is to make class time work a part of the grade a student receives rather than simply for the work turned in at assigned end dates. This sort of treaty between the students and teacher will help convince the former to work during assigned times (cf. Powell et al., 1985). The work grade system described by Polman (2000) has a student get either full credit, half credit, or no credit in a particular day, allowing a quantitative measure overall; by making this grade a significant part of the final assessment, this helps encourage students to perform needed tasks, and it helps indicate to the instructor which groups are actually trying to do their best. However, this assessment may not do well to help guide students, so rather than simply monitoring student activity for effort or lack thereof, part of the work grade should also consider if students are making inquiries to the teacher. It is unlikely that a group can work and not come across any issues, so their questions can both inform the instructor of their progress and indicate their effort in trying to complete their task.

A final consideration for communication in the classroom setting is allowing the students to be able to have a voice. In lecture-based teaching methodology, it is the instructor who dominates what information is conveyed and when, while PBL ought to become more student-centered. This means a change in the primary role of the instructor who instead must help the students express themselves to achieve learning rather than the instructor professing for the period. More completely, there should be an effort to create a "community of learners" by the participation of all parties in active roles (Brown, 1992; Rogoff, 1994). It is here that the instructor must apply scaffolding through various coaching strategies.

Collins et al. (1989) give three particular apprenticeship strategies which are useful recommends for PBL: learning on demand, coaching, and monitoring. This first strategy is to give students information pertinent to their project's subject matter when the students need it rather than simply lecturing and hoping the students will have memorized the facts so they can recall trivia for their project. This on-demand learning has been recommended by other groups that had found just-in-time lecturing to be the most profitable (Helle et al., 2006). Coaching differs from lecturing in that the teacher gives advice rather than information along with encouragement. This keeps the students upbeat and focused and helps them pursue more profitable lines of research. Monitoring denotes that the instructor continues to be aware of the progress of groups in their efforts; it means the teacher has an active role in determining the evolution of a project rather than the more passive role found in discovery learning. Integrated with these suggestions is the co-ownership of a project done by the students with the instructor; the teacher can make suggestions of what an interesting question may be, but students should ultimately decide (Polman, 2000; see also Pea, 1994). In this way students are more likely to work with the instructor at difficult points when making their project while still feeling they are in control of their research.

While student control of a project is necessary for them to develop their own learning context and thus better integrate their knowledge with other background knowledge, some pupils will struggle in coming up with projects or questions as well as issues with discovering useful resources. This will be especially true for students used to traditional methods if they desire these older ways over innovations like PBL. One can potentially avoid this problem if the instructor has a list of potential assignments or questions that a student may research along with the background knowledge of what sources are the most useful. Such a list

is more likely to be produced after the instructor has done several iterations of PBL courses, finding what projects turned out to be profitable. However, first-time PBL instructors do not have this luxury, but fortunately other teachers have published some projects that they found to be helpful (i.e. Capraro et al., 2010).

All of the above considerations have focused on the classroom, but now we look to the environment that students will occupy the most. Outside of the classroom, students will still need to put in a considerable amount of time into their project if they are to succeed. Both gathering information and analyzing data are time-consuming activities that cannot be done in short blocks of time in the classroom, but this also means that potential issues cannot be alleviated directly by the instructor. Communication through email can help, but it is no substitute for an actual discussion with the teacher. Moreover, unlike class time where it is possible that a work grade can be given, it is difficult to objectively gauge how much time students put into their projects when they are away from school. Again, one way an instructor can provide to encourage student work outside of the classroom are goal posts, setting deadlines for certain aspects of the project or the progress in working on the project; with more immediate deadlines and a more apparent idea of how much time is needed to complete a task, this should persuade the student to work after school hours on their problem. Additionally, what problems a student or group may encounter outside of class time can still be brought up to the instructor during the next class.

C. Administration

In an earlier section, some of the history of PBL was discussed, noting that it was made part of curricula in much of the Western world, diminished during the 1960s, and recovered again especially in central and northern Europe (Schäfer, 1988; Petri, 1991; see Figure 1) and is now widely discussed amongst STEM educators (cf. Capraro et al., 2010). While research had shown PBL to be effective, larger forces, namely economic and political, seem to be the primary culprit for their disappearance by the mid-late 20th century in the United States. Here the factors in focus concern administrative issues, including those caused by economic or political forces, and how they can affect the implementation of PBL.

Various businesses and other economic bodies have a keen interest in how their future workforce is developing, and so they make investments into schools or attempt in other ways to influence what subjects are taught. These sorts of interferences are well documented throughout the 20th century (Nasaw, 1979; Houghton, 1996; Polman, 2000). If vested interests want students to learn particular facts or skills, this will not be amenable to PBL instruction, which gives the student more freedom to explore a subject that they are attracted to and may have little relation to monetary interests. With usually tight budgets made even tighter now due to economic issues, as well as the community aspect of businesses, it is unlikely that various industries will not continue to influence the subject matter in schools, which in turn affects how those materials are taught. Similarly, political interests have a direct influence over what and how students are taught, especially in public schools. From standardized tests to disrepute concerning particular subjects, legal forces can undermine PBL. The general political climate can affect whether 'progressive' ideas such as PBL are more widely implemented or not (Cuban, 1990); with the launch of Sputnik, the American government pushed more for math and science classes with 'excellence' initiatives in order to create a competitive populace in the US against the Soviet Union; these initiatives were more rigid than the explorations of PBL and required a baseline of factual knowledge above other learning considerations sometimes describing as digging a trench a mile wide and an inch deep – very broad knowledge but with no depth (Sawyer, 2006). However, progressive thinkers held sway again after the civil rights movement and the Vietnam War, though not for long and not deeply enough to change teaching paradigms. We can see the limitations that PBL has faced with particular conflict between a curriculum and political entities described by Dow (1991), the "Man: A Course of Study" (MACOS) program from the early 1970s. This humanities course made various groups irate, from religious conservatives who balked at its evolutionary premises and undercutting of their cultural values to political conservatives that saw anti-American implications in the courses (see also the 2005 documentary Through These Eyes, featuring Dow). By 1975 federal funding of MACOS was withdrawn, and the course quickly died out afterward.

While direct interference with a particular PBL module is rare, the more common roadblocks governmental forces can effect are standardized tests for both state and federal assessment, such as found in the No Child Left Behind initiative. This often leads instructors into the strategy of "teaching to the test" that can increase test scores as this is the primary factor that matters in funding schools, a genuine interest for those in the upper echelons of the educational hierarchy. However, this minimizes learning outside the narrow range of questions that students are expected to answer, exasperating the "mile wide, inch deep" problem of curricula; this sort of instruction can even undercut students taking an examination if expectations for the test are in error (Wiggins & McTighe, 2005). It is perhaps standardized testing (which generally evaluate decontextualized knowledge) that is the greatest administrative barrier to PBL (Sawyer, 2006).

Here we do not provide ways to alleviate these problems as they are at a level that an individual teacher has little control. Large-scale socio-political forces can only be adequately redirected through collective efforts. As this focus is more in political science, these issues cannot be dealt with here.

Table 3. Considerations in PBL Implementation

Section	Feature	Consideration
Curriculum	Syllabus	Try to be thorough enough to minimize procedural questions
		Have clear grading criteria
		Have clear goalposts/due dates for parts of projects to assess student progress and provide feedback
		Spread out workload over period of project
	Scaffolding	Set boundaries, break down tasks into manageable pieces
		Provide a rationale for doing a given task
		Use tools to help with routine tasks to maximize time for reflection on subject material instead of procedural issues
		Use verbal prompting to help students articulate their answers and see potential issues with their ideas
Environment	Classroom	Groups set by instructor with members of differing ability levels, size around 3-4
		Community of learners: teachers and students in constant communication
		Apprenticeship strategies: learning on demand, coaching, and monitoring
		Time allocation: answer questions on subject matter over procedure as much as possible
		Best if students initiate inquiries with teacher
		Have confidential meetings
	Home	Considerable homework time needed
		Communication with instructor needed
		Goalposts help to keep students motivated to work outside of classroom
Administration	Business interests	Want particular skills more than deep knowledge
	Political interests	Problems with particular modules (i.e. MACOS)
		Implementing standardized tests with decontextualized questions (i.e. NCLB)

In summary (see Table 3), the effective implementation of PBL has numerous hurdles that must be overcome in order to maximize the utility of this teaching method as well as ensure that it remains in practice rather than degenerate into classical pedagogies. Many aspects, such as the curriculum and the learning environment, are directly controllable to a degree by the instructor, and precautions can minimize the stresses that PBL can bring about for students as well as teachers. Administrative problems are more difficult to control, but an awareness of them can help realize the issues and affect a proper response.

V. ASSESSING PBL IMPLEMENTATIONS

History indicates that any template can be improved, especially with a multi-variable subject such as teaching. This means that a system to examine how well a teaching module works and find ways to improve it must be included. Earlier Helle et al. (2006) was cited for their meta-analysis of PBL in post-secondary education, and they found a lack of careful examinations of the utility of their PBL curricula. A similar criticism by Belland et al. (2009) stated that various assessments had significant design flaws. What follows are a few tools to help indicate if the system for PBL de-

scribed above works comparatively better than others. These are testing methods or measurements that have been investigated elsewhere, so their validity is understood as well as their limitations. The combination of these various tools should help indicate where PBL units could be weak.

The apparatus proposed for examining the effectiveness of a give PBL module and any curricula based off it require a randomization process as well as a control group. The randomization element will help ensure that unconscious (or conscious) forces do not cause a teaching method to be given to those more likely to succeed or fail, and with a large enough sample size the randomization will help create a normal distribution of student abilities. A control group will also need to be established for comparison. One group should be given the PBL curriculum, another given a different curriculum (if we are comparing various PBL approaches), and another remaining with historically taught approaches to act as a control. The comparison between groups will make inferences from the data more reliable.

Next is how to gather data from these groups. The most informative tool for how well students understand physics material is a clinical-type interview, especially that composed by Inhelder and Piaget (1958). Interviews tend to be the best measure of student understanding as learners can be probed precisely to find the boundaries of their physics comprehension and to what extent an interviewer sees fit. This investigative tool can pinpoint what limitations students have before and after administration of the curricula of a given group, which will indicate what methods are most effective in teaching particular subjects. The interviews usually last ten to forty minutes and requires expert skills in interviewing as well as equipment for demonstration. This means this tool is very taxing in time and skills, and most teachers may be overwhelmed by such a demand. For interviews to be done on a large enough of a scale for statistical significance, outside researchers are necessary. This is further advisable since teachers who know their students could be biased in some fashion, while an outsider is less likely to be. Nonetheless, this tool is only for those who can afford the resources.

A more easily implementable method uses written tests, and a few such measurement tests have been developed over the years for STEM courses. For example, there is the Force Concept Inventory (FCI) and the Conceptual Survey of Electricity and Magnetism (CSEM) which are used for assessing student performance at the introductory level in college (Diff & Tache, 2007). FCI examines a student's understanding of Newtonian physics, including forces, rotation, and energy; while about 80% of pupils having taken college physics can recite the three laws of Newton, according to FCI only about 15% or less actually understood their meaning and implication (Hestenes, 1998). FCI then helps indicate the difference between repetition and understanding, and PBL should help contextualize force concepts better than traditional methods. Similarly, CSEM examines college level students' understanding of electromagnetism. Another common test is that developed by Lawson (1978), an examination of formal reasoning based upon Piagetian designs, which originally had a multiple choice aspect and a free response explanation section; a student first chose the answer to a physical situation from a give list of possible answers, and then had to write why this was a correct choice. Recently, the test has been revamped to become completely multiple choice but still holding to the two-question format for each concept. The limitations of the Lawson test are being explored (Bao et al., forthcoming), but it still has utility for grade-school applications.

What these various tests can do is establish how well students have come to understanding both the material and how to think about physics problems. In order to judge the effectiveness of the PBL module, an initial baseline of student performance before the implementation of a curriculum can be measured both for classes using and not using either PBL or PBL modules articulated above that take into consideration various shortcomings. A similar evaluation should be performed after the module has been completed. Assessing which method was better should consider not only final outcomes but also the level of growth of student knowledge; perhaps two methods of teaching will bring students up to the same point of understanding, but one method could be more advantageous to underperforming students. Standard practice in physics education research is to consider the normalized gain (g), defined as the difference between pre- and posttest scores divided by the difference between perfect posttest scores and actual pretest scores (Hake, 1998).

$$\mathrm{g} \equiv \frac{posttest - pretest}{100\% - pretest}$$

Such a measure, when averaged, is both better able to compare disparate grounds and it is less susceptible to student guessing (Stewart & Stewart, 2010).

Even with raw test score data, further analysis may be necessary before strong conclusions can be established. Another consideration should be the biases in test scores for gender, race, or socio-economic background. As mentioned before, PBL was shown to be particularly helpful to racial minorities, and other researchers have found a similar ability to establish equality (Boaler, 2002), but a proper control for these effects ought to be established. Fortunately, sociologists have developed models that control for these issues, such as by Roscigno (1998) who quantizes the effects. We can therefore normalize assessments; it may also be wise to evaluate how well PBL designs help groups at a disadvantage or what curricula are the most equitable.

In addition to the tests mentioned above, this evaluation could also be tested on a larger scale using SAT, ACT, and similar standardized test scores, specifically in science and mathematical reasoning, by comparing schools that do and do not implement PBL science courses. This may become easier to evaluate as a long historical baseline can be established before implementation and with many more pupils. Such a measure would probably have better statistics and be less prone to fluctuations of student performance. The historical baseline for a school can provide another way

Table 4. PBL Module Evaluation

Analysis Concerns	Designs and Methods	Tools/Explanations
Comparison	Control group	One group or prior class without PBL, another with PBL
	Randomization	Helps ensure reliable statistics
	Normalize for biases	Socio-economic status effects, etc.
Evaluation Methods	Individual interviews	Accurate, but time and energy consuming
		Need professional interviewers
	Standardized tests	Some designed for particular subject evaluation (i.e. FCI for classical mechanics)
		General assessment (i.e. SAT)
Stability	Surveys	PBL modules used over time?
		Do teachers return to classical practices?

to avoid biases that the SAT has, such as toward higher income households that can afford better schools and tutors or similar cultural biases in test scores; if the same school is examined, a similar population should be found, avoiding this bias in results. Nonetheless, as noted earlier, standardized tests have the weakness that they examine decontextualized knowledge, so these tests may not register the effects of PBL compared to lecture-based instruction. As such, standardized tests should not be used alone but in coordination with the other exams mentioned earlier and perhaps interviews.

While these tools will be useful for determining the effectiveness of student learning through PBL, another consideration is how well such a curriculum can remain established. A PBL module will only be effective long-term if it continues to be part of the teaching paradigm, so a second point of assessment is discovering if PBL tends to deteriorate into older paradigms. This can be assessed by survey, finding the number of teachers and/or courses that continue to apply PBL and see if it remains stable or grows. This measure can be useful in comparing other versions of PBL units; by comparing different schools or classes that use either unit, the stability of implementation can be understood. PBL modules that prove to be more resilient to degeneration will be preferred.

By considering all these points in evaluating a PBL module, it will be possible for educators to better tailor their curricula to their teaching objectives and ensure that their goals are in fact achievable. Caution is required in the use of any one tool for evaluating students as they all have their weaknesses, but they can still provide some information to help instructors in their efforts. Taken together, these evaluative methods should help PBL modules become the best that they can.

VI. CONCLUSIONS

PBL proves to be an exciting change in how mainstream teaching can be done, and fortunately research indicates that it is more effective that classical methods. The core component of student-centeredness as well as constant feedback between instructor and pupil allows students to not only learn better but also integrate their background knowledge into knowledge structures superior to those created by the collecting facts routine as seen in lecture-based instruction. However, there are pitfalls to doing PBL, namely its time-consuming nature, and various forces can degenerate PBL into older methods, especially if those difficulties are from larger forces beyond the classroom environment. Most important here are the considerations for what will make the implementation of PBL in the classroom more successful. Implementation is likely to discover other aspects worth adding to the watch list as experience shows what issues tend to arise during realization.

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