

# STEM Project-Based Learning

## An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach (2nd Edition)

Robert M. Capraro, Mary Margaret Capraro and James R. Morgan (Eds.)



*SensePublishers*

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An Integrated Science, Technology, Engineering,  
and Mathematics (STEM) Approach

Second Edition

*Edited by*

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## **PREFACE: OVERVIEW FOR THE DESIGN OF STEM PBLs**

### *Well-Defined Outcome and Ill-Defined Task*

Our definition for STEM PBL drives all of the design and implementation decisions discussed in this book. Therefore, a quick deconstruction of our definition is useful prior to reading through the chapters, reviewing our sample PBLs or designing your own.

As we were conceptualizing the book we did not want anyone to have to read the book in its entirety before beginning the planning and implementation process. Instead, we envisioned strategic reading or just in time reading. We believe the layout of the book is mostly sequential, following the 7 Design principles. We also wanted chapters to be readily accessible when questions arise during the implementation phase. So in Chapter 1 we intend that this chapter will help to explain what STEM PBL is and the rationale for using it for classroom instruction. Chapter 2 highlights the humble roots of STEM PBL and carefully articulates the history of the project method of instruction. In Chapter 3, it covers the theoretical underpinnings for designing STEM PBL activities and then to build on your first endeavor. Chapter 4 can be used to continually improve your projects. Once you build your own PBL and you want to start getting colleagues involved it provides the who, where, and when for using STEM PBL instruction. Once you have colleagues on board it is important to deal with the issues surrounding interdisciplinary teaching and learning in Chapter 6. Then as a team of teachers begins to build toward fully implemented projects it is essential to understand the relationship between Inquiry Learning and STEM Project Based Learning and questioning. Chapter 8 details the important role technology plays, not as an add on, but as the means for facilitating the teaching and learning process. No book on STEM PBL or chapter on technology would be complete without the topic of virtual worlds. The power of virtual worlds can energize STEM PBL instruction and maximize learning while providing important learning affordances. Because there are so many tangible instructional possibilities it is important to think about STEM PBL as an educational tool for all children, and Chapter 10 details the possibilities for Exceptional and Diverse Learners. Whenever a teacher tries to implement a new teaching method he or she often marks his or her success by the students' behavior and not by an objective examination of the effect on student learning. So because students will likely have to learn how to learn in a STEM PBL environment Chapter 11 details classroom management considerations. Hand in hand with classroom management are concerns for assessment, how, when, and what are explained in Chapter 12. The final two chapters deal with two issues of paramount importance, English Language Learners. These two topics are essential because STEM PBL should be for all learners and can incorporate what happens in the Social Studies class as well as be implemented into the social studies class. Finally, we provide many sample rubrics, forms, guidelines, samples, and preparation documents to assist you in implementing STEM Project Based Learning.

Well-defined outcome – The well-defined outcome comes from the dual influence of the engineering design process and high-stakes accountability and standards. An engineer always starts with an end in mind (e.g., span this river, minimize fuel consumption, etc.) and in today's high stakes testing environment so should designers of instruction. Our STEM PBL design process always begins with a measurable object in mind and typically includes the design of summative assessments prior to instructional design to ensure that the students will in fact meet the objective. In the best scenario, these summative assessments will include open-ended assessments that look a great deal like learning activities from the PBL and multiple choice questions that are similar in style and content to local, state, and national assessments that students will be taking in the future. This is NOT teaching to the test, it is designing to the objective.

Because the majority of our work is in the state of Texas, we have chosen to use Texas state standards (<http://www.tea.state.tx.us/teks/>) to model our design process but other local, state, or national standards that guide your instruction would be the beginning of your *well-designed outcome*. All of our STEM PBLs start with a well-defined outcome (could have been labeled as the primary objective). The well-defined outcome was developed through the integration of the secondary objectives and it is the integrated well-defined outcome that initiated the design process, informed our summative assessment design and all subsequent instructional design decisions. The secondary objectives are crucial as they define the integration and provide the STEM for our PBL. Group planning is also encouraged by including substantive secondary objectives. Secondary objectives are assessed to varying degrees (formative and summative) depending upon the intent of

## PREFACE

their inclusion. Please resist the temptation to pull a single concept out of a secondary objective and implement the PBL with that as the primary objective. If you change the well-defined outcome, you will need to change the PBL.

*Ill-defined task(s)* – The ill-defined task(s) are essential to the inquiry process. Too often, hands-on activities are verification of known - or at least taught – concepts. The ill-defined nature of STEM PBL requires higher order thinking skills, problem-solving, and increased content learning. One misconception about PBL in general is that it is chaotic or haphazard. Nothing could be further from the truth. Ill-defined is not ill-designed. The teacher must design tasks that allow for student investigation, multiple solutions, and engaging contexts all of which converge in a common understanding of the ill-defined outcome.

*Putting it all together in a STEM PBL classroom* – As a teacher, you and your students will need practice and support as you transition to STEM PBL tasks and learning. A simple suggestion, which may hasten the transition, is an extended 5-E model of instruction. We have chosen to use the 5-E model to communicate our design, but recognize that there are other appropriate inquiry models that can be modified to fit STEM PBL. Resist the temptation to tell the students what they are going to learn, let them learn it! But plan to let your students talk, plan to talk yourself, just don't talk first, last, or the most. We have included a limited number of examples of STEM PBLs that we have used in the past and recommend as well-tested exemplars for you as you learn to design and implement STEM PBLs. This is not a comprehensive list and we do not think that providing one would dramatically improve your chances of implementing STEM PBL. Your local and state standards are different, your resources are different, your potential partners are different ... and thus your STEM PBLs should be different. Good luck!

ROBERT M. CAPRARO AND SCOTT W. SLOUGH

# 1. WHY PBL? WHY STEM? WHY NOW? AN INTRODUCTION TO STEM PROJECT-BASED LEARNING: AN INTEGRATED SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) APPROACH

## INTRODUCTION

The belief that all genuine education comes about through experience does not mean that all experiences are genuinely or equally educative. (Dewey, 1938, p. 25)

STEM Project-Based Learning (PBL) requires a professional teaching force empowered with the skills necessary for designing learning experiences that maximize student potential. Therefore, effective STEM PBL requires teachers to experience high quality professional development to learn how to design high quality experiential learning activities. Not all professional development activities are created equal (Desimone, Porter, Garet, Yoon, & Birman, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001) and not all enactments meet the expectations of high quality professional development (Capraro, Capraro, & Oner, 2011; Capraro, & Avery, 2011; Han, Yalvac, Capraro, & Capraro, 2012).

Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PBL) integrates engineering design principles with the K-16 curriculum. The infusion of design principles enhances real-world applicability and helps prepare students for post-secondary education, with an emphasis on making connections to what STEM professionals actually do in their jobs. Our view of STEM learning is one in which the fields are all supportive and integrated where applicable with the design principles in Chapter 4 undergirding the problem solving processes contained in the project.

This book discusses STEM PBL and establishes a set of expectations for implementing STEM PBL. You may want to skim some chapters reading those chapters that hold promise to answer questions you already have while reserving some chapters for when you encounter questions as you implement STEM PBL in your own classroom. This brief chapter will outline some of the vocabulary, discuss the basic tenets of STEM PBL, and familiarize the reader with what to expect from implementing it in their school.

## CHAPTER OUTCOMES

When you complete this chapter you should better understand:

- the nature of STEM Project-Based Learning
- STEM PBL concepts and terminology

When you complete this chapter you should be able to:

- communicate using STEM PBL terms
- explain the basic tenets of STEM PBL
- make informed decisions about which chapters to read first

## OVERVIEW OF STEM PBL

### *Why PBL?*

Project-Based Learning has been around for many years and it has been undertaken in medicine, engineering, education, economics, and business. Project-Based Learning is often shortened to PBL, but this acronym is often confused with problem-based learning. The two terms are not synonymous. In this book, we endeavour to keep problem-based learning in lower caps to help you, the reader, differentiate the two when it is

necessary for us to discuss problem-based learning. Project-Based Learning is broader and often is composed of several problems students will need to solve. It is our belief that PBL provides the contextualized, authentic experiences necessary for students to scaffold learning and build meaningfully powerful science, technology, engineering, and mathematics concepts supported by language arts, social studies, and art. STEM PBL is both challenging and motivating. It requires students to think critically and analytically and enhances higher-order thinking skills. STEM PBL requires collaboration, peer communication, problem-solving, and self-directed learning while incorporating rigor for *all* students. STEM PBL builds on engineering design as the cornerstone and as the foundation on which students bring their compartmentalized knowledge of science, technology, and mathematics to bear on solving meaningful real-world problems.

#### *Why STEM?*

The idea of PBL is not new; however, what is new is the emphasis on STEM education and linking secondary education with post-secondary practices. It is common in post-secondary institutions for students to be required to work in groups to solve complex problems situated within larger projects. While problems and projects do not necessitate convergent solutions, students are required to explain their solutions and to be able to justify the suitability of a proposed solution to the specifications of the PBL. Commonly, this process has been termed problem solving and it is often expected to be taught in mathematics classes. However, STEM professionals engage in complex problem solving and in most cases there are multiple possible solutions each with its strengths and limitations. Therefore, it is important for secondary students to develop broad knowledge that allows them to be successful on high-stakes tests, but also develop the depth of knowledge to allow them to reflect on the strengths and limitations of their solutions. The STEM PBL process develops critical thinkers who will be more likely to succeed in post secondary institutions where these skills are essential. The focus on STEM in this book is different than most definitions that continue to consider STEM as four discrete subjects. STEM PBL acknowledges that learning and job success is interdependent and that expertise is built iteratively across all subjects, even when one has a particular focus one more than any other. Therefore, job success is dependent on the interaction of knowledge from within each and also across STEM disciplines. So student learning settings and expectations should mimic this very complex learning design – at least in part.

An additional advantage to integrating STEM and PBL is the inclusion of authentic tasks (often the construction of an artifact) and task-specific vocabulary through the inclusion of design briefs. After identifying the learning goals, the teacher develops expectations for the authentic task to be completed or the artifact to be constructed along with the necessary constraints to establish boundaries for the learning. The constraints are often included in the design brief and are the most basic of requirements often considered essential. Therefore, not meeting the constraints would indicate an inadmissible attempt. The design brief contains both the constraints and the criteria informed by knowing exactly which objectives or standards students will be expected to master. The criteria are measurable. These criteria help students know how they are progressing on the tasks and it is these criteria that inform assessment. In fact, it is the criteria that form the basis of all assessments used throughout the PBL.

#### *Why Now?*

As the pressures build and the pressure from external constituents force schools to relegate good teaching to the back burner while putting testing for accountability front and center, there must be an instructional model that provides students with high value tasks that foster rigorous subject matter engagement. We define STEM PBL as an *ill-defined task within a well-defined outcome situated with a contextually rich task requiring students to solve several problems which when considered in their entirety showcase student mastery of several concepts of various STEM subjects*. Well-defined outcomes include clear expectations for learning connected to local, state, and national standards *and* clearly defined expectations and constraints for the completion of the task. The ill-defined task allows students the freedom to interpret the problem, constraints, and criteria informed by their subject area knowledge to formulate diverse solutions that will meet the well-defined outcome. STEM PBLs engage students in authentic tasks that result in specific learning essential in the current standards-based educational model, while connecting K-12 and post-secondary education and addressing the future workplace learning needs.



### *Building a Common Language*

It is important to understand what is meant by somewhat common terms in relation to STEM PBL. For example, “brainstorming” is commonly used to simply generate ideas and not engage in the evaluation of any particular one. In addition, in PBL, brainstorming is used as a pedagogical technique to establish teams and encourage a common focus. It is during brainstorming sessions that teams develop shared knowledge and a group dynamic that will serve as the incubator for their work together and eventually will lead to their unique solution. The term relevance has to have many meanings, the usefulness of the education to life-long learning, meaningfulness to self, importance to society, real-world applicability, and finally the formation of moral decision making. In STEM PBL, relevance is not an oversimplification of these ideas just a prioritization that is used to align learning with formal standards or student expectations. So in STEM PBL we talk about educationally relevant and it is this educational relevance that facilitates the development of rigorous and challenging experiences for students.

An important consideration when deciding to adopt STEM PBL is that of the interdependent nexus of learning objectives, assessment, and student learning. It is common to refer to student objectives. The phrase “student objectives” has come to be interpreted in behavioristic terms. STEM PBL would be considered the polar opposite to behavioristic paradigms of teaching and learning, therefore, we use the term student expectations or SEs. We feel the term SEs is not laden with prior notions, but still conveys the message that teachers must use some form of objective, national or state standard, learning goal, or performance expectation in order to align teaching, learning, and assessment in this era of accountability. So rather than be stereotyped into a specific paradigm the perspective of this book is to accommodate many views and regardless of personal perspective, one can fit those views for describing what students will learn in STEM PBL.

Given the importance of establishing SEs, it is essential to also use some form of assessment to determine the extent to which students master the learning goals. PBL is well suited to rubric assessment but NOT to the exclusion of other forms of assessment. It is important to have a mix of assessments and to build student experience with as many forms of assessment as possible.

Many schools that adopt STEM PBL also establish a professional learning community (PLC). A PLC can be an important and very productive school-based initiative that provides for and sustains STEM PBL. The formation of a PLC facilitates discussion about roles and responsibilities, establishes group norms, and sets expectations for everyone involved in the PLC. Often PLCs have stakeholders from across the continuum, but it is just as common for school-based PLCs to have representation from a more limited set of stakeholders.

*What Is Engineering Design and Why in K-12*

Engineering design has many forms with varying numbers of steps. There is no single foundational model broadly accepted across all engineering schools or practicing engineers. Some engineering design models have as few as three steps while others can have 10 or more. Some engineering designs are partially linear with iterative portions, but some are completely iterative while others are hierarchical and linear. The steps are often formulated to meet specific needs. Our model depends heavily on its intended purpose, teaching and learning that rely heavily on problem solving and internalizing or learning new content. This is different from many other models with the intended purpose being quality control, parsimony of resources, elegance, or applicability.

*The Flow of the Book*

The book is designed to provide a modern STEM approach to PBL that is informed by research. It covers the typical major topics, but also includes a historical perspective, a modern perspective on assessment that works in symbiosis with high-stakes testing, and includes insights into the formation of PLCs and their impact on sustaining school change. It is not written as prescription or novel, we hope readers select chapters as they journey from dabbling in STEM PBL to mastery. This new edition is in a new format that allows duplication of the worksheet pages, lessons, rubrics, and observation instrument. We hope the new format is helpful to both teachers and workshop providers.

*Vocabulary for Reading the Book*

*Constraint.* Parameters established as part of the project to structure the deliverables of a PBL event. Constraints are placed on the design process and the product. Constraint is not synonymous with criteria. A constraint could be that a presentation must include research and contain a marketing component that lasts no more than three minutes, no two puzzle pieces can be the same, the boat must float for 2 minutes, or materials cannot be cut. All constraints must be met to have an admissible project.

*Criteria.* Items written to support specificity that can be ranked or may demonstrate the continuum between expert and novice knowledge of the learning outcome. Generally, it is these criteria that function as part of the assessment component. Designer defined criteria are used to select among plausible designs and may include a wow factor, personal insights, complexity, novelty, or cost.

*Design Brief.* The parameters for a PBL. The design brief contains the constraints, establishes criteria, may or may not establish evaluation standards, clearly communicates the deliverables, and outlines the conditions under which the PBL inquiry occurs.

*Problem-based learning.* PBL for the purposes here is the use of a problem statement that both guides the learning and any resultant activities to explore the topic. Generally, PBL is context rich but textually and informationally impoverished. The focus of learning is on individual and groups to (a) clearly identify what information they need to solve the problem and (b) identify suitable resources and sources of information.

*Professional Learning Community (PLC).* Communities of practitioners, students, administrators, community stakeholders, and district personnel whose mission is to facilitate the teaching and learning process where the goals are to establish common language, expectations, standards, to facilitate increased student outcomes. It is also not uncommon to have a more limited set of stakeholders depending on the level of district commitment.

*STEM Project-Based Learning (PBL).* An ill-defined task with a well-defined outcome situated within a contextually rich task requiring students to solve several problems, which when considered in their entirety, showcase student mastery of several concepts of various STEM subjects. PBL here is the use of a project that often results in the emergence of various learning outcomes in addition to the ones anticipated. The learning is dynamic as students use various processes and methods to explore the project. The project is generally information rich, but directions are kept to a minimum. The richness of the information is often directly related to the quality of the learning and level of student engagement. The information is often multifaceted

and includes background information, graphs, pictures, specifications, generalized, and specific outcome expectations, narrative, and in many cases the formative and summative expectations.

*Relevance.* Refers to the real-world connections that should be fostered in each PBL, it is also associated with facilitating student development of a personal connection to the project and fosters “buy-in” for solving individual problems presented in the project.

*Rubric.* May be co-developed with the students before the project starts and provides clear criteria that rank the extent to which a team or individual meet the expectations. Multiple rubrics can be developed to assess cooperation, collaboration, presentation, content, completeness, language, visual appeal, and marketing. The evaluator can be the individual, peers, teacher, administrator, or external stakeholder.

*Small Learning Community (SLC).* These are formed by ensuring that all the content area teachers (mathematics, science, social studies, reading/language arts) teach the same students and have common planning, behavior management plans, and performance expectations. SLC affords teachers the opportunity to become better acquainted with students and improves communication among teachers about student progress on common issues.

*Student Expectations (SEs).* Specify learning goals where the focus is on the verbs. Clearly defined student expectations facilitate the alignment of teaching, learning, and assessment.

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## 2. THE PROJECT METHOD IN HISTORICAL CONTEXT

### INTRODUCTION

Project-Based Learning (PBL) has been a long tradition in America's public schools, extending back to the 19<sup>th</sup> century to the work of Francis W. Parker and John Dewey. As a method for general education, the idea of project-based classroom instruction was co-opted from agriculture and the industrial arts and, after first being applied in the elementary schools, was extended to all grade levels. Initially focused on "real-world" problems with tangible, measurable outcomes, the project method was quickly adopted and applied to any activity of interest to students, however transient and/or insignificant. The lack of a succinct definition for the project method has prevented the assessment of its success, regardless, the "method" became the "current" model of instruction in all subjects for all students, often failing to meet the needs of children, teachers, or society. The project method, as a descriptive term for school *practice*, was replaced with child-centeredness and the activity curriculum. After a period of near obscurity, PBL has been reclaimed by educators to educate 21st-century students.

### CHAPTER OUTCOMES

When you complete this chapter you should better understand:

- the origins of the idea of the Project Method
- the early applications of the Project Method
- reasons why the Project Method failed to have a lasting influence in 20th-century education practice

When you complete this chapter you should be able to:

- explain the origins of the Project Method
- identify some of the major proponents of the Project Method
- explain how the lack of a clear definition of the Project Method contributed to its decline in the public schools
- explain how the idea of the Project Method changed into the ideas of child-centeredness and the activity curriculum

In this chapter, the authors present (1) a brief history of the project method, both before and after Kilpatrick's widely read and cited article and (2) some of the issues related to the application of the project method in public school classrooms. We also examine the definition of "project" and how that definition was applied to the use of the project method in the school.

When William Heard Kilpatrick published "The Project Method" in the *Teachers College Record* in September of 1918, he started the piece saying, "The word 'project' is perhaps the latest arrival to knock for admittance at the door of educational terminology" (p. 319). He also posed the following two questions:

... is there behind the proposed term ... a valid notion or concept which proposes to render appreciable service in educational thinking? Second, if we grant the foregoing, does the term "project" fitly designate the waiting concept? (p. 319)

Kilpatrick's questions encompassed the whole range of issues related to the "project method," both its history and application to practice. Over the next five years, many authors offered definitions and explanations for the project method and how it should be enacted in schools. However, the definitions were diverse enough to encompass almost any instruction and failed to give teachers specific criteria against which they could measure their practice and, in the end, satisfied neither the theorists nor the practitioners.

Kilpatrick is frequently cited as one of the most popular professors and often criticized scholars of the Progressive Era; ultimately, his career spanned six decades (Cremin, 1961, p. 220; Kliebard, 1986, p. 176; Ravitch, 2000, p. 178). At the time that he published “The Project Method,” however, Kilpatrick was struggling to earn a promotion to full professor at Teachers College at Columbia University. Before joining the faculty in 1911, Kilpatrick had been a student at Teachers College, studying under Dewey. Consequently, Dewey pragmatism and experiential learning philosophy shaped Kilpatrick’s pedagogical theories and, more specifically, his approach to the project method (Cremin, 1961, p. 215). The attachment of Kilpatrick to the project method in twentieth century educational literature is due to the fact that his article was reprinted tens of thousands of times all over the world (Cremin, 1961, p. 217; Kliebard, 1986, p. 159). Despite being identified as the father of the modern project method, Kilpatrick readily acknowledged that he is a late comer to the use of the term project, that he is unaware of its heritage, but that he sees value in using the term. “I did not invent the term nor did I start it on its educational career. Indeed, I do not know how long it has already been in use. I did, however, consciously appropriate the word to designate the typical unit of the worthy life described above?” (1918, p. 320).

Although Kilpatrick is unconcerned with pinning down the beginnings of the project method, other authors have located the origin of the term in agriculture, manual training, and domestic science (Horn, 1922), or with Dewey and others at Chicago and Teachers College (Parker, 1922b). Parker (1922b) also credits Francis W. Parker and C. R. Richards for popularizing the idea of pupil planning as part of the project process as early as 1901 (pp. 427-429). von Hofe (1916) wrote, “The sixth-grade pupils in the Horace Mann School are studying science regardless of every artificial division. The class chooses a project, something that has attracted attention and in which they are vitally interested. The teacher then presents the information to follow not the so-called logical development found in textbooks but the trend of thought of the pupils” (pp. 240-241). While not defining the practice as a “method,” von Hofe described a practice that would shortly become popularized as the project method.

Writing in 1997, Knoll states

Recently, however, historical research has made great progress in answering the question of when and where the term “project”-“progetto” in Italian, “projet” in French, “projekt” in German, and “proekt” in Russian-was used in the past to denote an educational and learning device. According to recent studies, the “project” as a method of institutionalized instruction is not a child of the industrial and progressive education movement that arose in the United States at the end of the 19th century. Rather it grew out of the architectural and engineering education movement that began in Italy during the late 16th century (Knoll 1991a, 1991b, 1991c; Schöller, 1993; Weiss, 1982). The long and distinguished history of the project method can be divided into five phases:

1590-1765: The beginnings of project work at architectural schools in Europe.

1765-1880: The project as a regular teaching method and its transplantation to America.

1880-1915: Work on projects in manual training and in general public schools.

1915-1965: Redefinition of the project method and its transplantation from America back to Europe.

1965-today: Rediscovery of the project idea and the third wave of its international dissemination (Knoll, 1997).

Still others push the origins back to the “Sloyd” system of manual training, which emphasized domestic projects for the purpose of building neatness, accuracy, and carefulness, and a respect for labor in a social context (Noyes, 1909). Sloyd education first took root in 1865 in Finland under the influence of Uno Cygnaeus, a devoted follower of Froebel and Pestalozzi – but gained widespread popularity at Otto Salomon’s school in Naas, Sweden (MacDonald, 2004, p. 306). During the 1870s and 1880s teachers and scholars from around the world traveled to Naas to undergo Salomon’s courses in sloyd. According to one such scholar, Evelyn Chapman (1887), Salomon’s *educational sloyd* was introduced into “France, Belgium, Germany, Austria, Russia, and the United States” and “even far-distant Japan” (p. 269). Given Cygnaeus’s admiration for Froebel, it is perhaps unsurprising that Chapman goes on to draw a connection between sloyd and kindergarten, “. . . in the adoption of the kindergarten system, the very soul of which is its response to the child’s need of activity and production; and sloyd is the same principle at work, only in a form suited to the growing powers of our boys and girls” (p. 269).

In the United States, perhaps the most prominent example was the Sloyd Training School for teachers in Boston, Massachusetts. According to its founder and principal, Gustaf Larsson (1902, p. 67), approximately 22,000 pupils were receiving instruction from its graduates in the year 1900. Notwithstanding, while there are clearly overlapping themes between the project method and educational sloyd, the extent to which sloyd influenced the project method remains unclear.

Unconcerned with these historical considerations, Kilpatrick's goal in his article was to lay out the pedagogical and psychological principles of learning on which the idea of the project was based and provide direction to teachers. He goes on to say that the purposeful act is the basis for a worthy life and that we admire the "man who is master of his fate, who with deliberate regard for a total situation forms clear and far-reaching purposes, who plans and executes with nice care the purposes so formed. A man who habitually so regulates his life with reference to worthy social aims meets at once the demands for practical efficiency and moral responsibility" (1918, p. 322). Kilpatrick, following the idea of Dewey and others that school is not for life but is life, continues to explain the value of a purposeful act, "As a purposeful act is thus the typical unit of a worthy life in a democratic society, so also should it be made the typical unit of school procedure. ... education based on the purposeful act prepares best for life while at the same time it constitutes the present worthy life itself" (1918, p. 323). Dewey's thought is often difficult to pin down, but the roots of Kilpatrick's ideas are consistently evident in Dewey's writings of the late nineteenth and early twentieth centuries. In fact, in his most notable work on education, *Democracy and Education*, Dewey quite directly connects education as a purpose of life. In one of his more concise statements on the issue he says, "The continuity of any experience, through renewing the social group is a literal fact. Education in its broadest sense, is the means of this social continuity of life" (Dewey, 1916, p. 2).

In his 1997 article, Knoll summarized Kilpatrick's ideas on the project

Kilpatrick (1925) defined the project as a "hearty *purposeful* act." "Purpose" presupposed freedom of action and could not be dictated. If, however, "the purpose dies and the teacher still requires the completion of what was begun, then it [the project] becomes a task"-mere work and drudgery (Kilpatrick, 1925, p. 348). Thus, Kilpatrick established student motivation as the crucial feature of the project method. Whatever the child undertook, as long as it was done "purposefully," was a project. No aspect of valuable life was excluded. Kilpatrick (1918) drew up a typology of projects ranging from constructing a machine via solving a mathematical problem and learning French vocabulary, to watching a sunset and listening to a sonata of Beethoven. In contrast to his predecessors, Kilpatrick did not link the project to specific subjects and areas of learning such as manual training or constructive occupations; the project did not even require active doing and participating. Children who presented a play executed a project, as did those children sitting in the audience, heartily enjoying it.

Despite Kilpatrick's efforts to ground the project method in Dewey's thought, seldom in the many articles and books that followed and explanations of the method of the project does one find either the connection between the purposeful act (the project) and preparation for democratic life or that education is life; the first seemingly is ignored, the second seemingly a given. One difficulty adopters of the project method encountered was, in addition to the attempt to apply a method used in manual training and agriculture to academic subjects and questions of its applicability to non-manual subjects (Ruediger, 1923), was the lack of a concise definition. Several authors questioned the appropriateness of the method for academic subjects. Ruediger found the project method inappropriate, writing

The fact that the project idea in its original meaning is not applicable to the teaching of academic subjects has given rise to a number of interesting yet confusing developments. As used in agricultural education, the project has reference to the use of productive activities for teaching purposes. ... something of objective significance is produced. A genuine vocational activity, somewhat circumscribed perhaps, is used for educative purposes. When we come to the academic subjects this idea of a project is not so easily realized. In reading, in arithmetic, in geography, and in history it is not easy for the pupil to produce something of inherent significance, something that society values regardless of personal sentiment. (p. 243)

Horn's criticism of the project method also went to the motivation and appropriateness of the application of the method to academic subjects. "The most serious confusion in recent years has resulted from the teaching of those who define the 'project' as a wholehearted, purposeful act project by children" (1922, p. 95) showed Horn's concern for the lack of preciseness and relationship to social utility and purpose. He wrote, in his 1922 article, that the original purpose of the project had been ignored and student interest and choosing had become guiding principles, rather than the nature of the project.

The worth of such "projects" [referring to traditional projects such as baking a cake, raising a plot of corn, building a bookcase] was measured by the degree to which they duplicated projects and activities found in life, by the degree to which they use the best materials and best methods, and by the degree of success that resulted. These "projects" may be defined as highly practical, problematic activities taken in

their natural setting and involving the use of concrete materials, usually in a constructive way. They are to be distinguished, in general, from other school activities in that: (1) they are organized more directly about the activities of life outside the school; (2) they are more concrete; and (3) they afford a better test of working knowledge. (p. 93)

Despite his best efforts, Kilpatrick contributed to the uncertainty of what is a “project” when he wrote

[T]he richness of life depends exactly on its tendency to lead one on to other like fruitful activity; that the degree of this tendency consists exactly in the educative effect of the activity involved’ and that we may therefore take as a criterion of the value of any activity – whether intentionally educative or not – its tendency to directly or indirectly to lead the individual and others whom he touches on to other like fruitful activity. (1918, p. 328)

It is the special duty and opportunity of the teacher to guide the pupil through his present interests and achievement into the wider interests and achievement demanded by the wider social life of the older world. ... Under the eye of the skillful teacher the children as an embryonic society will make increasingly finer discriminations as to what is right and proper. ... The teacher’s success – if we believe in democracy – will consist in gradually eliminating himself or herself from the success of the procedure. (1918, pp. 329-330)

Here then Kilpatrick sets the stage for the removal of the teacher from the process of choosing activities but this only occurs after the child has developed skill and knowledge necessary to choose wisely. The developed abilities of the child become less important than the child’s interest in later publications explaining the project method.

Kilpatrick is true to his ideas when he defined the project “to mean any unit of purposeful experience, any instance of purposeful activity where the dominating purpose, as an inner urge, (1) fixes the aim of the action, (2) guides its process, and (3) furnishes its drive, its inner motivation. The project thus may refer to any kind or variety of life experience which is in fact actuated by a dominating purpose” (Kilpatrick, Bagley, Bonser, Hosis, & Hatch, 1921, p. 283). This broad definition thus became the justification for most any type of educational activity that either motivated students or students said motivated them to learn, regardless of the social utility of the product or the ability of students to benefit from the activity or their maturity to allow them to conduct the activity.

Parker, in one of his 1922 articles, provided the briefest definition of project teaching by writing, “A pupil project is a unit of practical activity planned by the pupils” as a way of summarizing his longer definition of

The central element in project teaching is the planning by pupils of some practical activity, something to be done. Hence, a pupil-project is any unit of activity that makes the pupil responsible for such planning. It gives them practice in devising ways and means and in selecting and rejecting method of achieving some definite practical end. This conception conforms with the dictionary definition of a project as “something of a practical nature thrown out for the consideration of its being done” ... Furthermore, it describes with considerable precision a specific type of improved teaching that has become common in progressive experimental schools since 1900. (1922a, p. 335)

Parker thus places the interest of and planning of action by the student as the central tenet of the project method. He defines practical as “not theoretical” but does not ground the practical in utility or social purpose beyond that desired by the student.

Parker (1922a) reported, as an example of project teaching, a historical construction project where fifth-grade students constructed a castle from cardboard to illustrate life in the medieval period and wrote a poem and play concerning their work. Here one sees an example for which Ruediger later criticized the project method as producing something with no inherent significance but, which Parker justified, because he believed it had high motivational value.

Freeland, once a student teacher supervisor and principal of the teacher training school at Colorado State Teachers College, makes little distinction between problem and project teaching and wrote of their relatedness by first defining the problem method and then the project.

The problem is used to appeal to and develop the child’s thought (p. 6). ... The project may be defined in relation to the problem as something the child is interested in doing and which may involve thinking, but need not always do so. ... If it involves much thinking, it may contain problems (Freeland, 1922, p. 7).

[T]he project is different from the problem in that its essential feature is the provision of something to organize, investigate, or accomplish, rather than to stimulate thought. It may be a problem or part of a problem, and it may embrace problems. The more good problems a project affords the better it is for educational purposes. To afford something to do, the project must necessarily arise from the interests of the children. (Freeland, 1922, p. 45)

Freeland then still intends teachers to focus on the nature of the instructional act rather than focusing on the interest or intentions expressed by students. “The distinct advantage of the project method over the old topic or question and answer method is that it provides for continuous work on the part of the pupil rather than assignment from day to day” (p. 46).

The idea of definition became, to later authors, less of an issue than the adoption of the philosophy of the project method and its focus on children’s interests. Hosis and Chase, an associate professor and Teachers College and elementary school principal respectively, wrote in the Preface to their book, *Brief Guide to the Project Method*, “There is a limit to the amount of abstract theory which workers in the schools, and students preparing to join them can assimilate and apply” and “However imperfectly we have interpreted the project method, we believe that it is a fruitful concept of living, learning, and teaching, destined to influence profoundly the educational practices of the future, and that for good” (1924, p. iii). They conclude their introductory chapter with the sentences

[T]he Project Method means providing opportunity for children to engage in living, in satisfying, worthwhile enterprises – worth-while to *them*; it means guiding and assisting them to *participate* in these enterprises so that they may reap to the full the possible benefits. ... The Project Method, then, is a point of view rather than a procedure. [emphasis in original] (1924, p. 7)

In his 1926 book, *Modern Methods in High School Teaching*, Douglass, devotes separate chapters to Problem Teaching (chapter 10, pp. 295-322) and Project Teaching (chapter 11, pp. 324-356) making a clear distinction that projects could include problems and that problems could, at some point, become projects (pp. 324-325). Douglass, while making a distinction, sees the classification of an activity as a “problem” or a “project” as something teachers should not spend a lot of time on.

The underlying principles of procedure for problems and projects are essentially the same. Problems and projects possess very much the same values, and the merits of them as teaching procedures are based on the same psychological facts. It is not necessary, or desirable even if possible, to attempt here to draw a sharp distinction between the two. (p. 324)

Teachers are inclined to waste much valuable time in quibbling over what technically constitutes a project and what does not. An activity may technically constitute a project and yet be a very inferior educational activity. Merely being a project does not necessarily carry with it merit. A good problem, yes, even a good, old-fashioned, arbitrary, autocratic, daily assignment and recitation, is a much better teaching procedure than a poorly managed project. Not much good can come from merely learning the definition of a project. What is important for teachers is to appreciate the psychological principles which lie behind the project, and which account for its merit and effectiveness. (p. 326)

A little over 20 years later, in another version of the text, Douglass and Mills (1948) devote only 8+ pages to the project method as a part of a chapter on Teaching Units of Learning and 9+ pages to problem teaching as part of a chapter on Questions and Problems in Teaching. The authors cite Douglass’ 1926 definition of project in describing a project. “The project as used in a teaching is a unit of activity carried on by the learner in a natural and lifelike manner, and in a spirit of purpose to accomplish a definite, attractive, and seemingly attainable goal” (Douglass, 1926, p. 325; Douglass & Mills, 1948, p. 209).

Although early in his 1918 article, Kilpatrick emphasizes the connection between a whole-hearted purposeful activity and the social environment in which the activity takes place (p. 320), the ideas of whole-hearted and purposeful came to dominate the defining attributes of the activity.

And, while in 1918, initially emphasizing the necessity or importance of individualized self-directed motivation on the part of the student in choosing the purposeful activity, by the time he writes his 1925 book, *Foundations of Method*, Kilpatrick he has accepted the fact that the teacher may have a role in the planning and encouragement of interest in the project “We have, so far, not based any argument on the child’s originating or even selecting (in the sense of his deciding) what shall be done. So far, all that we have claimed will be met if the child whole-heartedly accepts and adopts the teacher’s suggestion” (1925, p. 207).

Douglass adheres more closely to Kilpatrick's original statement on self-selection as he includes as one of the characteristics that a project must include as "The learner approaches the task in an attitude of purposefulness; it is a self-imposed task, rather than one imposed arbitrarily by the teacher or the course of study" (Douglass, 1926, p. 325). Douglass does not however ignore the role of the teacher in planning and assisting students in the selection and management of projects. "As in the case with any teaching procedure, the project method in itself does not provide a complete educative situation. Merely having students purposing, planning and executing projects may or may not be good procedure, depending upon what projects are being completed and the nature of the procedure followed" (p. 341). This statement was followed by 8 criteria a teacher should use in selecting projects.

By the mid 1920s, the project method, which seemingly had something for every student and teacher, had been used to justify the child-centered and activity movements where all curricular plans were to begin with the interests of the child, even if the child was not motivated to have interests. These concerns were not missed by those promoting the project method, even as the idea of the project was being developed. Bonser, an associate professor at Teachers College wrote

A second danger of misinterpretation is that of assuming that all expressed interests of children are of equal worth. By such an interpretation, that which is trivial or relatively insignificant is permitted to divert efforts from activities which in themselves lead to higher levels of interest and worth. ... One very important function of the teacher is to select and direct interests and activities of children so that they may continuously lead forward and upward to higher stages. (Kilpatrick et al., 1921, pp. 298-299)

In attempting to use the interests of children, many teachers are tempted simply to "turn the children loose," and to allow them to follow any interests which they individually express, or to do nothing to stimulate desirable interests if such are not expressed. This results in indulgence rather than direction, in a form of anarchy rather than of orderly procedure. It has already been noted that all interests and activities are not of equal worth. It is the providence of the teacher to select, stimulate, and direct activities whose worth is high and leading forward toward objectives of unquestioned value. (Kilpatrick et al., 1921, p. 302)

Of all the speakers in the symposium on the project method (Kilpatrick et al., 1921), Hosis was the only one to reiterate Kilpatrick's early emphasis on democracy as his fourth point.

The project method is the application of the principles of democracy. Any one who will undertake to put into effect in his school the factors of socialization as set forth by Professor Dewey, namely, common aims, the spirit of cooperation, and the division of labor, will find that he is using the project method. No special devices for socializing the recitation will be necessary. (p. 306).

Later, in continuing the concern over the over-generalization of the tenets of the project method, Hosis and Chase (1925), in their chapter on "Dangers and Difficulties," warn against mechanistically turning control of the class over to students.

First, let us observe that the project idea should not be interpreted as a doctrine of *laissez faire*. The fact that the project teacher invites the pupils to assume a large measure of responsibility does not mean that she turns the school over to them. Both the community and the individual are to be served. The school is intended to provide a selected and controlled environment. If this were not so, the education of the children might as well be left to the more or less accidental ministrations of other agencies. (p. 86)

The reaction to the student-centeredness of the project method began almost as it was gaining popular acceptance. Curriculum theorists and practitioners were concerned over the lack of direction and purpose of the method. "According to Dewey, the method of surrounding the pupil with materials but not suggesting an end result or a plan and simply letting pupils respond according to whim, was ridiculous" (Tanner & Tanner, 1980, p. 295). Rugg and Schumaker, in their 1928 work, *The Child-Centered School*, wrote, "We dare not leave longer to chance – to spontaneous, overt symptoms of interest on the part of occasional pupils – the solution to this important and difficult problem of construction of curriculum for maximum growth" (p. 118).

The project method thus led to the notion that activity on the part of students was a measure of success and critical to learning. By the 1930s, the project method, as seen in schools, was under attack by the very person who supposedly was one of the originators of the method, John Dewey. Dewey was concerned that teachers had abandoned their proper role in education. "It is the business of the educator to study the tendencies of the young so as to be more consciously aware than are the children themselves what the latter need and want. Any other course transfers the responsibility of the teacher to those taught" (Dewey, 1934, p. 85). Also, by the

1930s, public schools were under scrutiny and attack for their perceived role in either not preventing the Great Depression or not “fixing” the Great Depression once it had begun and educational innovation began to fade.

In summarizing the failure of the child-centered project method, Tanner and Tanner wrote

... experience had made it abundantly clear to many educational theorists that a curriculum based solely on the spontaneous interests of childhood was an impossibility. Such a program could have no sequence and no predetermined outcomes, not even predetermined psychological outcomes. Even a play school had to have objectives and a program that was planned to meet those objectives. Otherwise, the child might as well stay home. (1980, pp. 296-297)

Projects, as a form of child-centeredness, again appear on the educational scene in the 30s in the form of the *Building America* Series, edited by Paul Hanna and sponsored by the Social Frontier group at Teachers College. Rugg, also a member of the Social Frontier group at Teachers College, identified the project method as a useful method in social reconstruction at the national level (Rugg, 1933). In his book, *Educational Frontier*, Kilpatrick (1933) discusses the social and educational reconstructivism movement of the 1930s. More specifically Kilpatrick addresses the need to reform the education system to prepare students for life in contemporary society – a society that requires collaborative efforts to solve problems. In this book, Kilpatrick offers a societal justification for using the project method in schools to achieve social reconstruction.

Later, in the immediate post-war period of the late 1940s and early 1950s, in an attempt to meet the needs of a changing society where more students enrolled in and graduated from high school, the project method reappeared in the form of the life adjustment or continuing life situations movement led by Florence Stratemeyer, again from Teachers College. Just as the project movement had been criticized for its attention to the immediate interests of children, so too was the life-situations curriculum.

Although the aim of this curriculum is to meet the needs of children and youth throughout their lives, needs also determine the choices of the problems to be studied. ... Like Kilpatrick, Stratemeyer and her associates stressed that not all children’s interests are equally valuable ... but, as in the case of Kilpatrick’s project method, it is preferable of the problems to be based on the child’s immediate concerns rather than on adult claims of children’s needs. (Tanner & Tanner, 1980, p. 387)

The various teaching innovations of the previous 50 or so years came under attack in the 1950s and soon disappeared from classrooms. The project method had a brief revival in the 1960s in response to the perception that education was failing the nation in science and mathematics. Educators again took an interest in the motivation of children to learn, thinking “that the thrill of discovering scientific concept autonomously would not only result in more effective learning but also instill in children the desire for further, more significant, discoveries” (Tanner & Tanner, 1980, p. 403). However, as Tanner and Tanner write, “this time the model was discipline-focused, not social-problem focused. Discover teaching was a disciplinary effort to teach children to think like scientists instead of children” (p. 403).

#### THE PAST AND THE FUTURE OF PROJECT LEARNING

As a popular method for general education in the early to mid 20th century, the project method borrowed its theory from agriculture and the industrial arts education and applied that theory to all subjects. However, lacking a clear definition, educational leaders and teachers often used their “definitions” to justify classroom activities driven solely by student interest, regardless of the educational value of the activity. Some (e.g., Douglass 1926, Hosis and Chase 1924) tried to prevent the overgeneralization of the term in classrooms; few practitioners listened and the focus became the interests of students. The social upheavals of the Great Depression and World War II refocused parents and leaders on societal needs rather than the wants of learners. Despite the brief activity in the later 1940s of the life-adjustment movement, the project method was thoroughly rejected by educational leaders as failing to meet the needs of children, teachers, or society.

In the last 10 years, augmented by research on learning and the effect of the learning environment on the learner, Kilpatrick’s goal of explaining the pedagogical and psychological principles of learning has come closer to being realized. The next chapter, the *Theoretical Framework for STEM PBL*, provides guidelines for implementing PBL in today’s classrooms. Although the question of applying the project method to academic subjects was never answered in the 20th century, STEM PBL illustrates that the project method is appropriate for academic subjects.

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