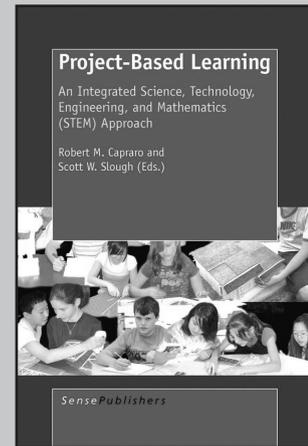


## Review

# Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach

<b>Title:</b>	<i>Project-Based Learning: An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach</i>
<b>Editors:</b>	Robert M Capraro & Scott W, Slough Rorrison
<b>Publisher:</b>	Sense
<b>Year:</b>	2009
<b>Price:</b>	\$ 54.00 Paperback \$ 99.00 Hardback
<b>ISBN-Paperback:</b>	9789087906375
<b>ISBN-Hardback:</b>	9789087906382
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This publication from Sense is a collection of invited essays. As they explain in the preface to the book, the editors are on the faculty of the Department of Educational Administration and Human Resource Development at Texas A&M University and have been actively involved in supporting the development of the curriculum for a network of STEM (Science, Technology, Engineering, Maths) centres across Texas. They are committed to educational approaches that support both equity (a lack of achievement gaps based on such things as race, sex or socio-economic factors) and excellence – virtually all children reaching high standards of achievement.

Developing practical, workable, applicable, powerful classroom tools to accomplish equity and excellence in all of our schools is what got us into PBL  
(pvii, emphasis in original)

The book has 13 chapters plus an extended Appendix but, surprisingly for a book of this nature, no Index. Each chapter starts with an introduction and a set of 'Chapter Outcomes' outlining some things that the reader will be able to 'better understand' and 'be able to' do; an approach that is unusual in texts of this type but very helpful (this reader found) in focussing the reader's attention.

The first chapter, by the editors, provides a brief rationale for the foci on PBL and STEM and for the use of the former in the teaching of the latter. Their claim is that:

...PBL provides the contextualized, authentic experiences necessary for students to scaffold learning and build meaningfully powerful STEM concepts...  
(p2)

The authors briefly summarise the flow of the book (noting that the chapters are designed to stand alone and be read in any order and that this inevitably leads to some overlap in content) and define a number of key terms used.

Slightly oddly, a short section titled 'Why Now' rather fails to provide a rationale for why the time is right for PBL-based STEM teaching.

The second chapter provides a helpful and detailed historical overview of the development of 21st century PBL from its 19th century roots in project-based educational methods. The difficulties, found from the earliest days, of defining what is meant by a 'project' are explored as are the arguments around the applicability of a practically-oriented approach to teaching in less practical (i.e. 'academic') subjects. The ill-defined relationship between PBL and the idea of 'problem'-based teaching is noted and the way that the originally reasonably well-articulated (if slightly ill-defined) definition of a problem-based approach to teaching became associated with and diluted by more general child-centred and activity-based 'progressive' models of education – and was thus swept away along with these models when the tide of educational opinion turned against them. The chapter ends on a positive note however:

In the last 10 years, augmented by research on learning and the effect of the learning environment on the learner, (the) goal of explaining the pedagogical and psychological principles of learning (through PBL) has come closer to being realized.

(p17)

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The third chapter outlines a theoretical framework for the use of PBL to support learning in STEM subjects with the aim of providing practical support for readers to implement PBL components into their teaching. Emphasising the close relationship between inquiry-based learning and PBL, the framework outlined has two main threads; the first, drawn from the design of effective learning environments, emphasises making content accessible, making thinking visible, helping children learn from each other and promoting autonomy and lifelong learning. The second thread, drawn from the 'learning sciences', emphasises the importance of children's pre-existing knowledge, the need for feedback, revision and reflection, the importance of teaching for understanding and the role of metacognition. This discussion is supported by a series of classroom vignettes that exemplify the ideas being outlined.

The chapter ends with a description of an evolutionary, or staged, approach to developing PBL, describing a continuum that supports a graduated movement from traditional approaches to learning towards those where the learner is acting as a fully-fledged researcher of new (to them, at least) knowledge. The authors note that this continuum can be used to support teachers in developing their practice, but that it also describes the development of a learner's journey in PBL from novice to researcher. The authors note that:

...it takes three to five years for meaningful changes in curriculum and instructional practices following a professional development experience (which) must be spent by stakeholders to consistently advocate for and pursue significant change in teacher, student and community behaviour.

(p34)

It may be picky, but the chapter is slightly marred by the insertion of a statement of physics that is plain wrong: "Newton's law of Gravity states that objects with larger mass attract objects of smaller mass". A book on the teaching of STEM should get basic science right.

The fourth chapter, "Designing Engineering PBL", focuses on engineering, 'the design process' and project management. Compared to other chapters this is weakly referenced. After a brief description of why the authors believe engineering is a rich context for PBL, the first part of the chapter describes in some detail the authors' view of the (by implication, engineering) design process as a systematic six-step process. This highlights a more general weakness of the book for a UK reader; what the authors actually mean by 'STEM' is not well-defined and the 'T'

element is treated in a very cursory manner or as a tool through which 'STEM' teaching can be supported, rather than as a distinct discipline. Most UK educators working in D&T would have a much more nuanced (and less linear) view of the way in which design unfolds within their subject.

A short section in the middle of the chapter outlines, again in a very systematic way, the steps through which a project should unfold from the 'Project Design Brief' onwards. Somewhat confusingly the chapter ends by aligning the six-step design process to a five-step instructional model and arguing that they tie in well through a detailed description of this alignment that repeats much of the material from the description of the six-step process.

Chapter 5 is titled "The Etiology of STEM PBL: linking engineering and Education". However, 'etiology' suggests a concentration on causal matters whereas this chapter is much more focussed on process issues. Repeating to some extent the material in chapter 2, there is a summary of the history of PBL and a comparison with problem-based learning. The chapter then goes on to discuss the changes in philosophy and in role that will be required of a 'traditional' teacher wishing to implement PBL and the changes required of students as the teaching they experience changes. The last part of the chapter discusses problem design noting that:

...PBL problems (should) be appropriate, ill defined, collaborative, authentic and promote self-directed learning. (p61)

The discussion here, having explored the features quoted above, goes on to also look at the problem-solving process, cooperative learning and assessment and evaluation and does so in terms that are much more helpful to teachers of D&T than the preceding chapter.

In the sixth chapter the discussion moves on to implementation of PBL in STEM with the spotlight on 'Who, When and Where'. The discussion of 'Who' encompasses not just teachers and students but also the important roles that administrators and community partners have. Unfortunately the section on 'When' PBL should be implemented doesn't really engage with the question, focussing instead on aspects of 'How', such as pupil motivation, the nature of ill-defined tasks and the importance of group work. The section on 'Where' PBL should be implemented outlines arguments for its use at all stages of education from elementary schools to Higher Education.

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The seventh chapter examines some key factors that can influence the implementation of PBL; in particular the role of national state and local standards (the US equivalent of England's National Curriculum), the role of tasks and artefacts in designing effective PBL and the importance of managing student expectations. In discussing standards the content is very specific to the US situation, but the overarching point is that standards (in the English context, the National Curriculum and exam specifications) cannot be ignored but can be met through well-designed PBL activities. The chapter goes on to explore the principles of good project selection, emphasising again the importance of starting with an ill-defined (or open-ended) task, but one whose central purpose will be the development of some kind of artefact. The authors argue that is the central place of the artefact that distinguishes PBL from other inquiry-based pedagogies. So, although tasks in PBL are ill-defined, the outcomes should be well-defined.

Chapter eight turns to the knotty problem of developing learning activity that is interdisciplinary, since the ill-defined nature of PBL tasks is always likely to drive student activity in ways that cross subject boundaries. The chapter starts with a discussion of what interdisciplinary teaching looks like by comparing it to traditional (subject-bound) teaching as well as to other approaches that involve some linking between subjects. A continuum of PBL curriculum integration is described and suggests a path that teachers and schools might take in a journey from single-subject teaching to fully interdisciplinary activity. Throughout, the importance of planning is emphasised and some of the issues that can arise when interdisciplinary teams are brought together are explored. The chapter ends with an honest examination of both the advantages and limitations of an interdisciplinary approach to PBL along with some examples of interdisciplinary PBLs from the literature.

The ninth chapter concentrates on the use of professional learning communities (PLC) to support the implementation of PBL. Following a brief description of what is meant by a PLC the author goes on to note that developing an effective PLC is 'messy work and tough work'. The author's own experience working within and supporting PLCs is used to illustrate a range of factors that can help develop a successful PLC.

The focus of the tenth chapter is on the use of 'technology' to support PBL. Rather disappointingly this is focussed solely on the use of a range of generic ICTs and ignores subject specific tools almost entirely (there is a nod in the direction of data logging in science). D&T tools that support digital designing and making through CAD/CAM, electronic circuit design and programmable

control gain no mention at all. That is not to say that the chapter is without merit; a wide range of both applications and web-based resources is referenced with a particular focus on tools that support collaboration.

Supporting the needs of 'exceptional and diverse' learners is the subject of the eleventh chapter; that is, those who in the UK we characterise as the gifted & talented or having special educational needs (this includes those for whom English is not the first language). The first part of the chapter is taken up by clearly and carefully characterising the particular needs of specific groups within the broad heading of 'exceptional and diverse'.

The authors go on to note that PBL:

...has child centeredness, extended time, well-defined outcomes and an interdisciplinary mission as essential elements. (p141)

They then take these elements of PBL and describe how each is relevant and significant for particular groups of exceptional and diverse pupils. Very helpfully the authors outline some of the common features of these pupils and the challenges that these bring – as well as discussing ways that teachers can meet these challenges particularly well through PBL. The chapter finishes with a good number of practical suggestions for ensuring that the needs of all students are met when engaging in PBL.

The twelfth chapter has classroom management concerns at its heart and it provides a great deal of useful and sensible advice on the particular issues for class management that PBL is likely to produce. These include task design (again – but this time with a focus on features of behaviour management) and managing group work. The advice provided is detailed and clearly written by authors with substantial experience of working with students in PBL activities.

The thirteenth and final chapter explores the issues that PBL raises for assessment, starting with a discussion of the roles of summative and formative assessment in PBL and noting that although the main focus of the chapter is on formative assessment:

Any educational innovation that fails to provide measurable impact on high-stakes assessment is doomed. (p175)

A big focus of the chapter is on the integration of assessment with teaching through the use of appropriate rubrics with an extended example rounding off the chapter.

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An extended appendix provides some exemplar PBL activities.

As the chapter notes above should have made clear, there is a great deal of unevenness in the quality and usefulness of the chapters suggesting a very light touch from the editors. In particular 'STEM' is not well-defined and technology as a subject discipline is effectively invisible making it a lot less useful for D&T teachers than it could have been.

That said, the general content describing what PBL is and how it can be implemented is nevertheless relevant and useful to the D&T community, providing a foundation to help us think about how the relationship between D&T and other subjects (including, but not limited to STEM subjects) can be developed to improve children's experiences and learning.