Problem-based Learning: An Overview

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PBL is a total approach to education. In PBL there is a curriculum of carefully selected and designed problems. And there is a PBL process, which, among other things, replicates the commonly used systematic approach to resolving problems or meeting challenges. Student and teacher roles are redefined. Students assume the responsibility for learning and teachers become facilitators: stimulating and guiding students' in their problem solving and self-directed learning.

(Barrows & Kelson, 1993, p. 2)

A Problem

- Used in a class for students preparing to be teachers
- Research informing practice
- In Pembleton School District, in a diverse urban elementary school, test scores have been falling for the last few years. Concerned parents are complaining (see supplemental docs)
- Let’s take 10 min to work on this
- PBL whiteboard:
  - https://docs.google.com/document/d/1dseduVtTnm1Y75sS5DNAeBX4S24uUTL7PLfa-umKino/edit

Overview

- What is problem-based Learning?
  - Goals of PBL
  - Key components of PBL
  - PBL as a strategy for curriculum development
  - Assessment in PBL
- Research on PBL
- Future directions

What is PBL?

Key Features of Problem-based Learning (PBL)

Learning is situated in meaningful problems that are:

- Ill-structured
- Selected to afford coverage of curriculum

Small, collaborative groups

- Students discuss alternative causal explanations
- Allow students to compare their ideas with others

Facilitator provides support for learning

Structured whiteboard

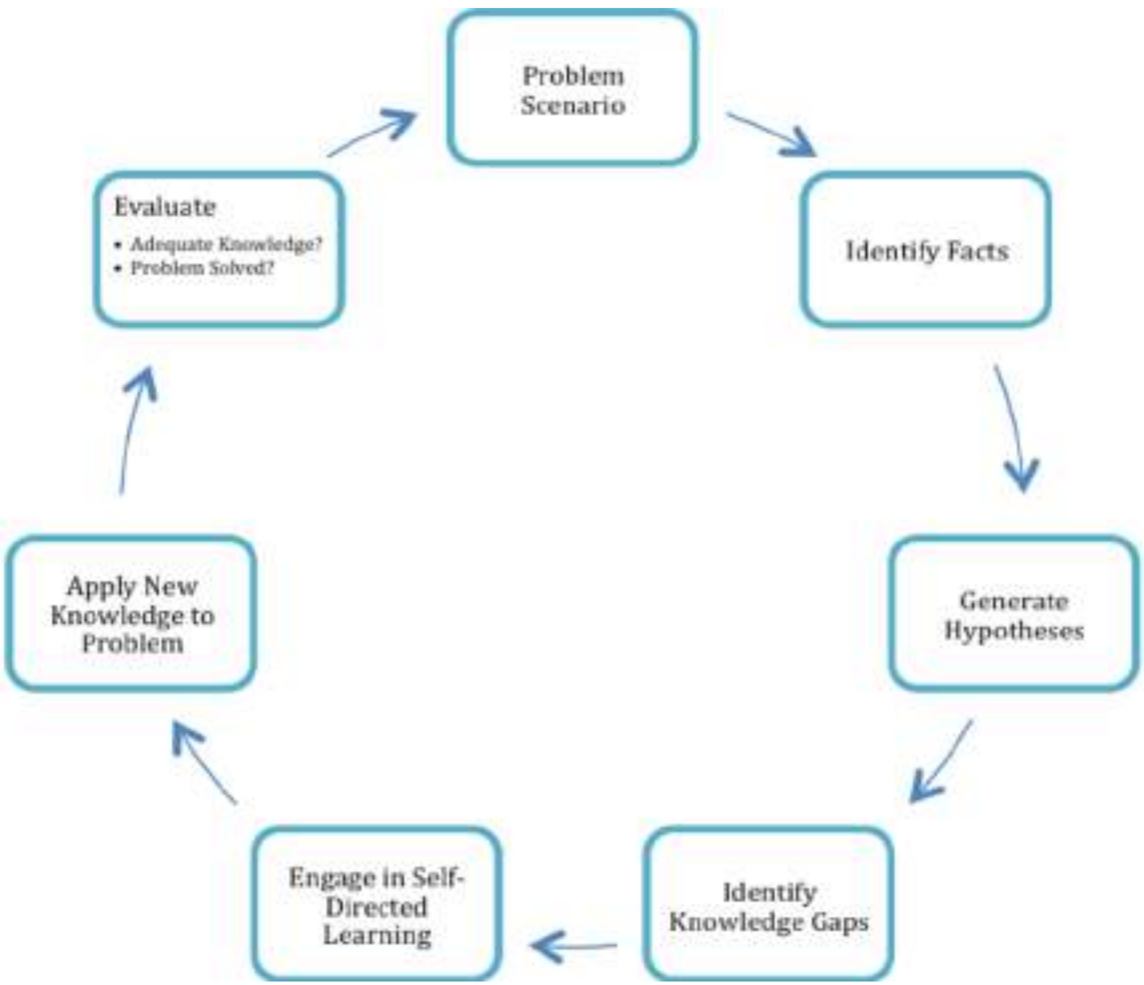
Goals of PBL

Help students develop:

- Flexible knowledge
- Effective problem-solving skills
- Self-directed learning skills
- Effective collaboration skills
- Intrinsic motivation

How do we do PBL?

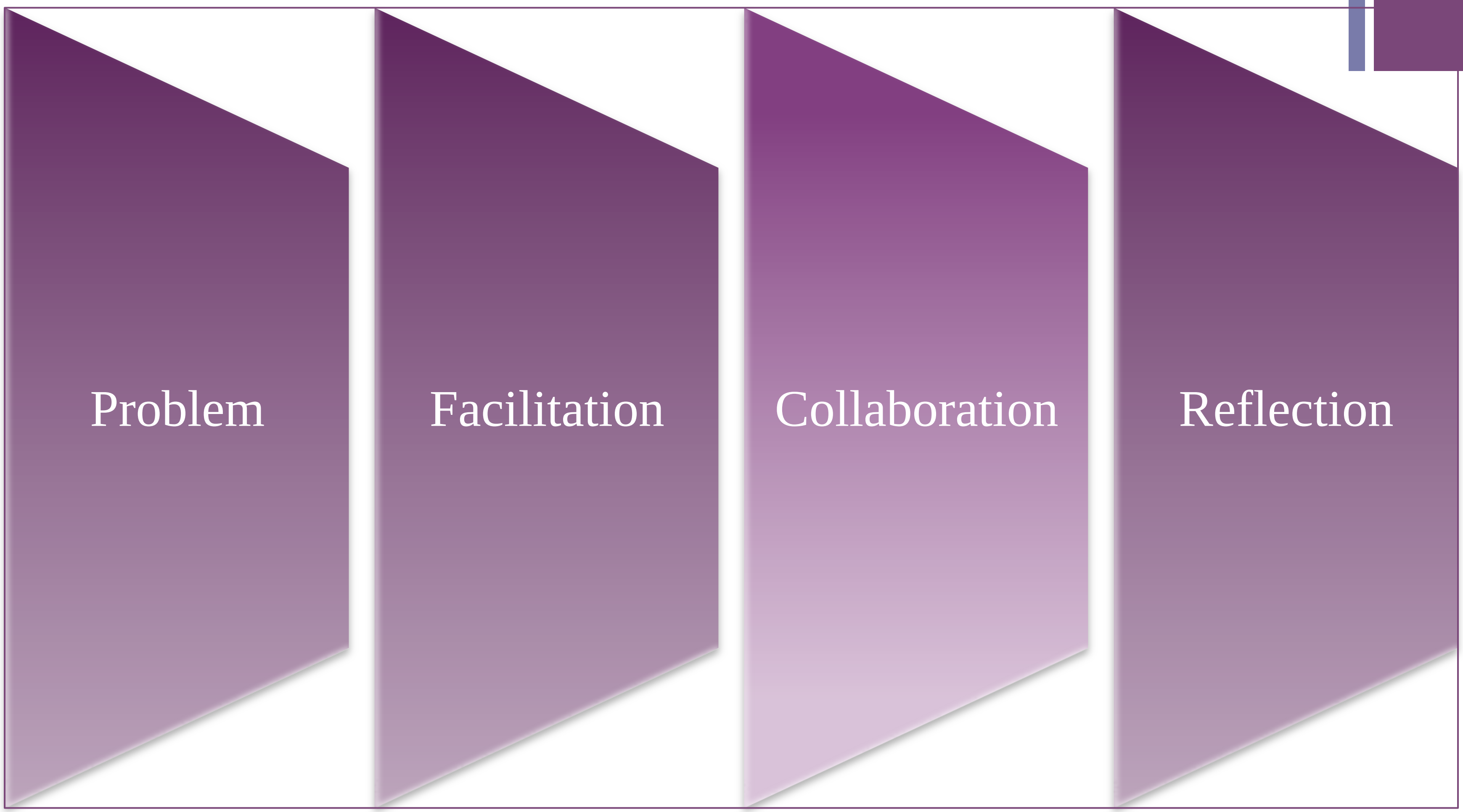
+ PBL Tutorial cycle



Structured Whiteboard

Facts	Ideas	Learning Issues	Action Plan
Hazardous chemical Near population center	Minimize onsite storage Provide safety training Improve early warning systems	What are the safety standards for cyanide storage? What technology is available to safely store hazardous chemicals?	Call EPA to find out standards

Key components of PBL



The Role of the Problem

- Good problems are:
  - Complex, ill-structured, open-ended
  - Must be realistic and something that learners can relate to
  - Provide feedback on learner effectiveness
- Design problems and strategic performance problems → greatest achievement benefits
- Ill-structured problems can → high quantity of problem-relevant interactions BUT need good facilitation

The Role of the Facilitator

- PBL as cognitive apprenticeship (Hmelo-Silver, 2004, Collins, 2006)
  - Make key aspects of expertise visible
  - Models problem solving strategies, reasoning, SDL strategies
  - Monitor agenda
- Guides development of critical thinking skills through repertoire of strategies that build on student thinking

Facilitating PBL: What do you notice?

Hmelo-Silver & Barrows, 2008

Facilitation Strategies

- Building on student discourse
- Focusing attention
  - Constrains space
- Pushing for explanation
  - Makes knowledge public and open for discussion
  - See limits of knowledge
- Revoicing (O'Connor & Michaels, 1993)
  - Take an idea put out by student and make clear for other students
  - Legitimates different students
  - Make sure important idea don't get lost
  - Move group along in process
- Map between symptoms and hypothesis
  - Goal: Elaborate causal mechanism
- Generate/ evaluate hypotheses
  - Goal: Help students focus their inquiry; Examine fit between hypotheses and accumulating evidence
- Summarizing
  - Goal: Ensure joint representation of problem; Establish common ground
  - Help students synthesize data
- Encourage construction of visual representation
  - Goal: Construct integrated knowledge structure that ties mechanisms to observable effects

(Hmelo-Silver & Barrows, 2006)

Collaboration

- Makes thinking public
- Supports social knowledge construction as students build collaborative explanations
- Distributes:
  - Expertise
  - Cognitive workload
- May need support for collaboration:
  - Scripts
  - Roles

Reflection

- Critical for learning and transfer
- Helps learners:
  - Relate new understanding to prior knowledge
  - Tie general concepts and skills to problem specifics
  - Develop better strategies for learning and problem solving

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PBL as Curriculum

- What do students need to learn?
  - Focus on big ideas
- Develop a curriculum matrix
- Designing problems
  - Under what circumstances is knowledge needed?
    - Common problems
    - Situations that are less common but really important
  - Sources
    - Newspaper/ Current Events
    - Community problems
    - Professional problems (e.g., evaluating business plans)
- Map problems to curriculum matrix

Example Curriculum Matrix

Learning Objectives	*Problems*		
	'Indecisive Isabelle '	*'Timmy Trouble'*	*'Please see and advise'*
Term 1: Students will develop an understanding of:			
❑ the clinical speech and language studies course	√		
❑ the nature of the SLT profession and related services	√	√	√
❑ the concepts, terminology and issues related to normalcy and difference		√	√
❑ their own values and attitudes to disability		√	√
Term 2: Students will have			
❑ knowledge and awareness of differing interpersonal style and how these may impact on clinical relationships	√	√	
❑ begun to address the principles of change in the clinical context	√	√	√
Term 3 : Students will			
❑ understand context and content of clinical transaction		√	√

+ Example Matrix for Single Problem

Syllabus Component	Problem Component							
	P	NH_3	NO_3^-	Hard-ness	BOD	Halo-carbons	Fecal coliforms	Oil & grease
Lab Techniques								
Preparing solutions; dilutions	✓	✓	✓	✓	✓	✓	✓	✓
Making up buffers	✓			✓			✓	
Standardization	✓	✓	✓	✓	✓	✓		
Calibration	✓	✓	✓			✓		
Distillation		✓						✓
Keeping a good notebook	✓	✓	✓	✓	✓	✓	✓	✓
Instrumentation and Analytical Methods								
Titrations				✓				
UV–vis spectrophotometry	✓	✓	✓					
Gas chromatography						✓		
Solvent extraction						✓		✓
Electrochemistry					✓			
Gravimetric analysis								✓
Infrared spectroscopy								✓

Assessment

- Assessment for learning
  - Support learning
  - Providing feedback
    - Teachers
    - Students

- Assessment of Learning
  - Certification of meeting standards
  - Program evaluation

Assessment in PBL

- Tensions
  - Ensuring both group and individual assessment
  - Keeping it student centered
- Formative
  - Self- and peer-assessments
  - Rubrics provide feedback on performance
  - Monitoring content space (Hmelo-Silver, 2013)
- Summative
  - Analysis of student artifacts
  - Individual performance assessments
  - Progress tests

Using PBL in Large Classes

- Floating facilitator model
- Peer facilitation
- Scaffolding the facilitator
  - Large post-it notes around room for recording whiteboard
  - Technology
- Adding more structure
  - Mix of small group and whole class discussion
  - Group accountability through reporting to whole class
  - Intersperse mini-lectures based on learning issues
- Need to understand tradeoffs

What do we know about PBL

- PBL used in range of settings
  - K-12 (e.g., Mergendoller et al., 2006; Brush & Saye, 2008; Torp & Sage, 2002)
  - Higher education (e.g., Duch, Groh, & Allen, 2001; O' Grady & Alwis, 2002; Ram, 1999)
  - Engineering e.g., (Abrandt Dahlgren & Dahlgren, 2002; Ge et al., 2010; Newstetter, 2006)
  - Business (Capon & Kuhn, 2004;Hallinger & Lu, 2012)
  - Educational leadership and teacher education (Bridges & Hallinger, 1997; Derry, Hmelo-Silver et al., 2006; Zhang et al., 2011)
  - Medical and health professions (e.g.,Bridges et al., 2012; Gijbels et al., 2005; Hmelo, 1998, Ertmer et al., 1996; Schmidt et al., 1996; Schmidt & Moust, 2000, etc.…)
  - Workplace learning (O' Mahony et al., 2009)

Constructing flexible knowledge

- Results are mixed
- Effects of PBL depend on what is measured (Gijbels et al., 2005; Walker & Leary, 2009)
- Variability among different disciplines (Walker & Leary, 2009)
- Variability among different educational levels (Walker & Leary, unpublished data)

Effects of Assessment Type (Gijbels et al., 2005)

TABLE 3
Main effects of problem-based learning

Outcome	Signif. +	Signif. –	*N*	Average effect sizes: Unweighted	Average effect sizes: Weighted (*CI* 95%)
Concepts	3	5	21	–0.042	0.068 (+/– 0.864)^{ns}
Principles	17	1*	15	+0.748	+ 0.795 (+/– 0.782)
Application	6	0*	13	+0.401	+0.339 (+/– 0.662)^{ns}

Assessment Level (Walker & Leary, 2009)

Table 2. *Assessment level outcomes.*

Assessment Level	sig. +	sig. -	$N_{outcomes}$	d_w	CI_{Lower}	CI_{Upper}
concept	19	15	73	-0.043	-0.092	0.005
principle	12[a]	4	40	0.205	0.142	0.268
application	28	0	60	0.334	0.287	0.382
mixed (concept & application)	0	0	1	0.168	-0.357	0.692
missing	9[a]	2	27	0.067	0.018	0.115
all	68[a]	21	201	0.127	0.101	0.152

[a]Significant ($p < .05$) sign test on the vote count analysis.

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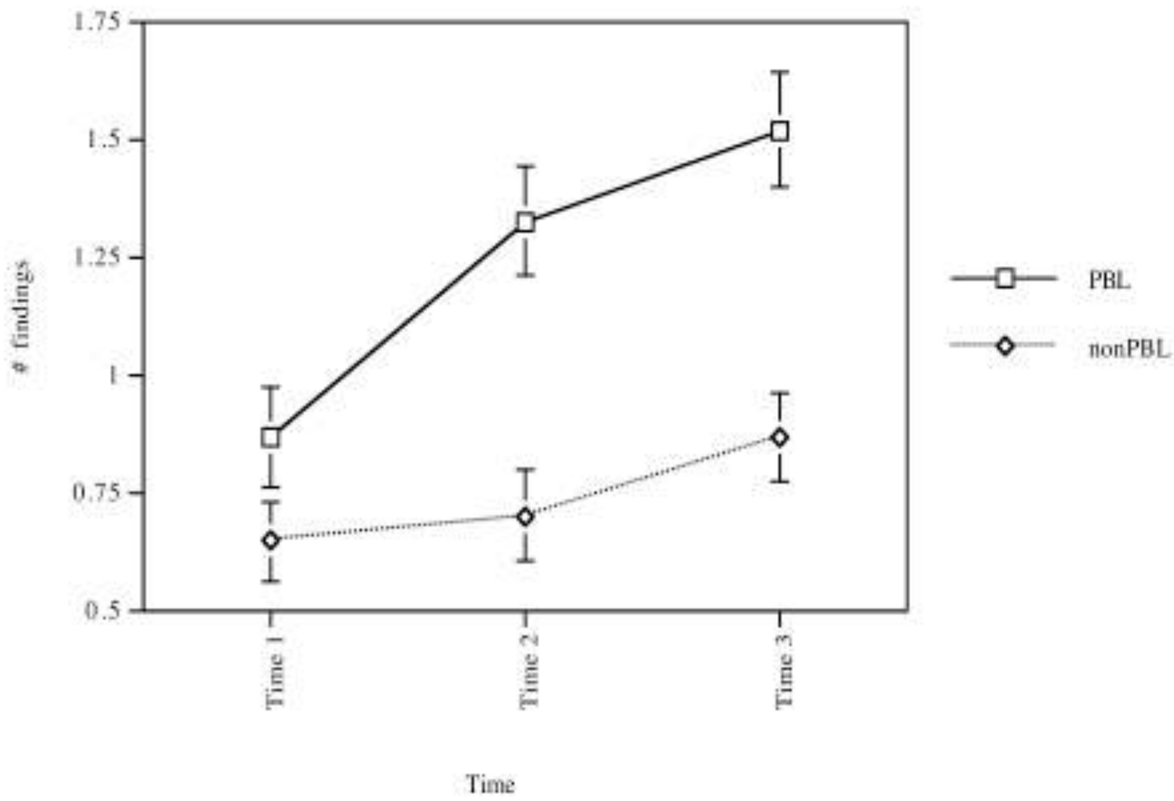
Medical context

- PBL student provide more elaborated explanations but more errors than traditional students (Patel et al., 1993)
  - Single problem, sampling issues
- PBL students more likely to generate accurate hypotheses, coherent explanations, and apply science concepts (Hmelo, 1998)
  - 6 problems, longitudinal design
- PBL students more accurate than traditional curricula (Schmidt et al., 1996)
  - 30 case vignettes

Coherence of explanations (Hmelo, 1998)



Effects of PBL Beyond Medicine

- Medicine has been the focus of much research, less in other disciplines
- Large effects in teacher education, small overall effects in medicine and sciences (Walker & Leary, 2009)

Table 1. *Discipline area outcomes.*

Discipline	sig. +	sig. -	$N_{outcomes}$	d_w	CI_{Lower}	CI_{Upper}
teacher education	1	0	4	0.635	0.443	0.827
other	5	0	13	0.482	0.307	0.658
social science	3	0	6	0.299	0.100	0.499
allied health	5	0	22	0.258	0.179	0.336
business	3	0	6	0.159	0.026	0.292
medical education	45[a]	16	133	0.085	0.056	0.115
science	4	4	12	0.062	-0.063	0.187
engineering	2	1	5	0.048	-0.197	0.292
all	68[a]	21	201	0.127	0.101	0.152

[a]Significant ($p < .05$) sign test on the vote count analysis.

Higher education

- Use of PBL in statistics → some learning gains (Derry et. al., 2000)
- Reliable pre to post test gains in engineering (Hmelo et al., 1995)
  - No comparison group
- Quasi-experimental study of pre-service teachers in technology-supported PBL environment showed reliable gains (Derry et al., 2006; Hmelo-Silver et al., in press)
- Business students better at applying knowledge to writing integrative essays (Capon & Kuhn, 2004)

Primary and secondary education

- Use of PBL with gifted high school students show knowledge gains (Gallagher & Stepien, 1996)
  - Increased retention over time (Dods, 1997)
- Design problems showed increased pre- to post gain compared with no treatment control in middle school (Hmelo, Holton, & Kolodner, 2000)
  - Students also demonstrated some misunderstandings
- High school economics (Mergendoller, Maxwell, & Bellisimo, 2006)
    - Large scale study showed increased knowledge gains compared to traditional courses

Effect of Level of Education

Level	Mean	Std	N
Grade school	-0.44	1.34	2
Middle school	0.38	1.13	5
High school	0.26	2.18	13
Vocational/technical/college	0.33	1.86	37
Graduate/professional	0.15	2.45	144
Adult/continuing education	0.78	2.05	2

Walker & Leary, 2009 unpublished data

Problem-solving Skills

- PBL students transfer reasoning strategies (Hmelo, 1998; Patel et al., 1993)
  - Use of hypothesis-driven reasoning strategies on novel problems
- Improvement in problem finding (Gallagher, Stepien, & Rosenthal, 1992)
- Improves over time (Hmelo-Silver, Chernobilsky, & Nagarajan, 2009)
  - Initially can be difficult
  - Requires support and reflection

Self-directed Learning

- Multifaceted process (Evensen, 2000; Hmelo-Silver et al., 2009; Jeong & Hmelo-Silver, 2009)
- Students become more self-directed as they advance in their programs (Loyens, Magda, & Rikers, 2008)
- Dependent on levels of self-regulation (Ertmer, Newby, & MacDougall, 1996)
  - Low SRL learners may have difficulties adapting, focus on facts
  - High SRL learners value learning from problems, focus on analysis and reflection

Self-directed Learning

- Students need to adapt to demands of PBL (Evensen, 2000; 2001)
- Students engage in high frequencies of monitoring their learning in tutorial sessions themselves (Hmelo-Silver & Barrows, 2008; Yew & Schmidt, 2009)
  - But this may require considerable support
  - Facilitator can play important role

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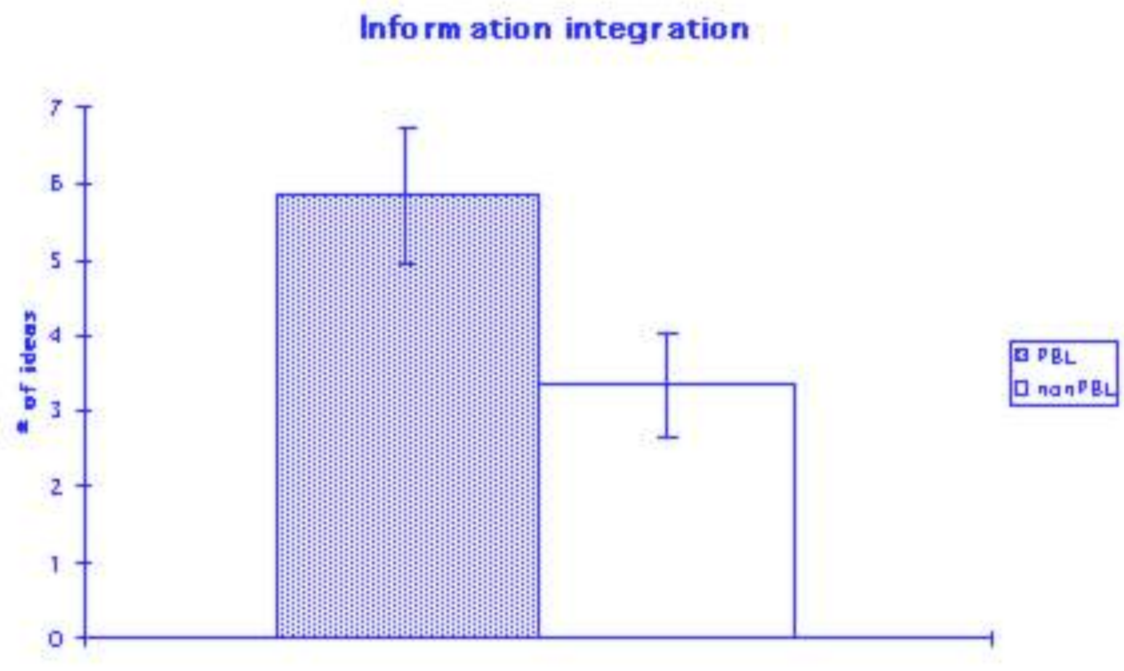
Self-directed Learning

- PBL students more likely to transfer hypothesis-driven information search to SDL and integrate new information (Hmelo-& Lin, 2000)



Using Resources

- PBL students more likely to use self-selected resources rather than faculty-selected resources (Blumberg & Michael, 1992; Shikano & Hmelo, 1995)

- Comparisons of more and less successful student groups of preservice teachers (Jeong & Hmelo-Silver, 2009)
  - Successful learners :
    - Wider exploration of non-required resources, making sure that they know what is available.
    - Deeper exploration of required/recommended resources

Collaboration

- Group functioning affects learning outcomes and motivation (Schmidt & Moust, 2000)
- Student discourse focus on collaboratively refining ideas and constructing explanations (Hmelo-Silver & Barrows, 2008)
- Not all students respond to collaboration well (Abrandt Dahlgren & Dahlgren, 2002; Evensen et al., 2001; Hmelo-Silver et al., 2008)
- Quality of collaboration improves over time (O'Mahony et al., 2009)
- Quality of collaborative discussions affected by:
  - Quality of problem (Kapur & Kinzer, 2007; Schmidt & Moust, 2000)
  - Facilitator (Schmidt & Moust, 2000; Zhang et al., 2008)
  - Group composition and experience

Motivation

- Increased satisfaction with medical students (e.g., Vernon & Blake, 1993)
- PBL course in statistical reasoning has had mixed satisfaction (Derry et al., 2000)
- Evidence of intrinsic motivation in veterinary students (Ertmer et al., 1996)
- Students highly engaged in technology-intensive secondary history PBL unit (Brush & Saye, 2008)
- Task value and self-efficacy predict achievement (Nagarajan, Hmelo-Silver, & Chernobilsky, 2005)

Challenges to Implementing PBL

- Skilled facilitation
- Teacher and student beliefs about learning
- Good problems
- Matching problems to curriculum
- Physical setting

Future Research?

- Understanding what we have good evidence for
- Where are the gaps?
  - Outside medical education
  - Younger learners
  - Incomplete descriptions of PBL models
  - Problem types
  - Assessment
- How can we scaffold PBL?
- Professional development for faciliting PBL/ inquiry
- Role of technology
- Understanding the trade-offs in design decisions

Questions?

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