Does coop work- research

**July 2004** *Journal of Engineering Education* **1**

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**ABSTRACT**

**This study examines the evidence for the effectiveness of active**

**learning. It defines the common forms of active learning most**

**relevant for engineering faculty and critically examines the core**

**element of each method. It is found that there is broad but**

**uneven support for the core elements of active, collaborative,**

**cooperative and problem-based learning.**

**I. INTRODUCTION**

Active learning has received considerable attention over the

past several years. Often presented or perceived as a radical change

from traditional instruction, the topic frequently polarizes faculty.

Active learning has attracted strong advocates among faculty looking

for alternatives to traditional teaching methods, while skeptical

faculty regard active learning as another in a long line of educational

fads.

For many faculty there remain questions about what active

learning is and how it differs from traditional engineering education,

since this is already “active” through homework assignments

and laboratories. Adding to the confusion, engineering faculty do

not always understand how the common forms of active learning

differ from each other and most engineering faculty are not inclined

to comb the educational literature for answers.

This study addresses each of these issues. First, it defines active

learning and distinguishes the different types of active learning

most frequently discussed in the engineering literature. A core element

is identified for each of these separate methods in order to differentiate

between them, as well as to aid in the subsequent analysis

of their effectiveness. Second, the study provides an overview of relevant

cautions for the reader trying to draw quick conclusions on

the effectiveness of active learning from the educational literature.

Finally, it assists engineering faculty by summarizing some of the

most relevant literature in the field of active learning.

**II. DEFINITIONS**

It is not possible to provide universally accepted definitions for

all of the vocabulary of active learning since different authors in the

field have interpreted some terms differently. However, it is possible

to provide some generally accepted definitions and to highlight

distinctions in how common terms are used.

*Active learning* is generally defined as any instructional method

that engages students in the learning process. In short, active learning

requires students to do meaningful learning activities and think

about what they are doing [1]. While this definition could include

traditional activities such as homework, in practice active learning

refers to activities that are introduced into the classroom. The core

elements of active learning are student activity and engagement in

the learning process. Active learning is often contrasted to the traditional

lecture where students passively receive information from

the instructor.

*Collaborative learning* can refer to any instructional method in

which students work together in small groups toward a common goal

[2]. As such, collaborative learning can be viewed as encompassing all

group-based instructional methods, including cooperative learning

[3–7]. In contrast, some authors distinguish between collaborative

and cooperative learning as having distinct historical developments

and different philosophical roots [8–10]. In either interpretation, the

core element of collaborative learning is the emphasis on student interactions

rather than on learning as a solitary activity.

*Cooperative learning* can be defined as a structured form of group

work where students pursue common goals while being assessed individually

[3, 11]. The most common model of cooperative learning

found in the engineering literature is that of Johnson, Johnson

and Smith [12, 13]. This model incorporates five specific tenets,

which are individual accountability, mutual interdependence, faceto-

face promotive interaction, appropriate practice of interpersonal

skills, and regular self-assessment of team functioning. While different

cooperative learning models exist [14, 15], the core element

held in common is a focus on cooperative incentives rather than

competition to promote learning.

*Problem-based learning* (PBL) is an instructional method where

relevant problems are introduced at the beginning of the instruction

cycle and used to provide the context and motivation for the learning

that follows. It is always active and usually (but not necessarily)

collaborative or cooperative using the above definitions. PBL typically

involves significant amounts of self-directed learning on the

part of the students.

**III. COMMONPROBLEMS INTERPRETINGTHE**

**LITERATUREONACTIVELEARNING**

Before examining the literature to analyze the effectiveness of

each approach, it is worth highlighting common problems that engineering

faculty should appreciate before attempting to draw conclusions

from the literature.

***A. Problems Defining What Is Being Studied***

Confusion can result from reading the literature on the effectiveness

of any instructional method unless the reader and author

**Does Active Learning Work? A Review**

**of the Research**

[QA1]

take care to specify *precisely* what is being examined. For example,

there are many different approaches that go under the name of

problem-based learning [16]. These distinct approaches to PBL

can have as many differences as they have elements in common,

making interpretation of the literature difficult. In PBL, for example,

students typically work in small teams to solve problems in a

self-directed fashion. Looking at a number of meta-analyses [17],

Norman and Schmidt [18] point out that having students work in

small teams has a positive effect on academic achievement while

self-directed learning has a slight negative effect on academic

achievement. If PBL includes both of these elements and one asks if

PBL works for promoting academic achievement, the answer seems

to be that parts of it do and parts of it do not. Since different applications

of PBL will emphasize different components, the literature

results on the overall effectiveness of PBL are bound to be confusing

unless one takes care to specify what is being examined. This is

even truer of the more broadly defined approaches of active or collaborative

learning, which encompass very distinct practices.

Note that this point sheds a different light on some of the available

meta-analyses that are naturally attractive to a reader hoping

for a quick overview of the field. In looking for a general sense of

whether an approach like problem-based learning works, nothing

seems as attractive as a meta-analysis that brings together the results

of several studies and quantitatively examines the impact of the approach.

While this has value, there are pitfalls. Aggregating the results

of several studies on the effectiveness of PBL can be misleading

if the forms of PBL vary significantly in each of the individual

studies included in the meta-analysis.

To minimize this problem, the analysis presented in Section IV

of this paper focuses on the specific core elements of a given instructional

method. For example, as discussed in Section II, the core element

of collaborative learning is working in groups rather than

working individually. Similarly, the core element of cooperative

learning is cooperation rather than competition. These distinctions

can be examined without ambiguity. Furthermore, focusing on the

core element of active learning methods allows a broad field to be

treated concisely.

***B. Problems Measuring “What Works”***

Just as every instructional method consists of more than one element,

it also affects more than one learning outcome [18]. When

asking whether active learning “works,” the broad range of outcomes

should be considered such as measures of factual knowledge,

relevant skills and student attitudes, and pragmatic items as student

retention in academic programs. However, solid data on how an instructional

method impacts all of these learning outcomes is often

not available, making comprehensive assessment difficult. In addition,

where data on multiple learning outcomes exists it can include

mixed results. For example, some studies on problem-based learning

with medical students [19, 20] suggest that clinical performance

is slightly enhanced while performance on standardized exams declines

slightly. In cases like this, whether an approach works is a

matter of interpretation and both proponents and detractors can

comfortably hold different views.

Another significant problem with assessment is that many relevant

learning outcomes are simply difficult to measure. This is particularly

true for some of the higher level learning outcomes that are

targeted by active learning methods. For example, PBL might naturally

attract instructors interested in developing their students’

ability to solve open-ended problems or engage in life-long learning,

since PBL typically provides practice in both skills. However,

problem solving and life-long learning are difficult to measure. As a

result, data are less frequently available for these outcomes than for

standard measures of academic achievement such as test scores.

This makes it difficult to know whether the potential of PBL to

promote these outcomes is achieved in practice.

Even when data on higher-level outcomes are available, it is easy

to misinterpret reported results. Consider a study by Qin et al. [21]

that reports that cooperation promotes higher quality individual

problem solving than does competition. The result stems from the

finding that individuals in cooperative groups produced better solutions

to problems than individuals working in competitive environments.

While the finding might provide strong support for cooperative

learning, it is important to understand what the study does *not*

specifically demonstrate. It does not necessarily follow from these

results that students in cooperative environments developed

stronger, more permanent and more transferable problem solving

skills. Faculty citing the reference to prove that cooperative learning

results in individuals becoming generically better problem solvers

would be over-interpreting the results.

A separate problem determining what works is deciding when

an improvement is significant. Proponents of active learning sometimes

cite improvements without mentioning that the magnitude of

the improvement is small [22]. This is particularly misleading when

extra effort or resources are required to produce an improvement.

Quantifying the impact of an intervention is often done using effect

sizes, which are defined to be the difference in the means of a subject

and control population divided by the pooled standard deviation

of the populations. An improvement with an effect size of 1.0

would mean that the test population outperformed the control

group by one standard deviation. Albanese [23] cites the benefits of

using effect sizes and points out that Cohen [24] arbitrarily labeled

effect sizes of 0.2, 0.5 and 0.8 as small, medium and large, respectively.

Colliver [22] used this fact and other arguments to suggest

that effect sizes should be at least 0.8 before they be considered significant.

However, this suggestion would discount almost every

available finding since effect sizes of 0.8 are rare for any intervention

and require truly impressive gains [23]. The effect sizes of 0.5 or

higher reported in Section IV of this paper are higher than those

found for most instructional interventions. Indeed, several decades

of research indicated that standard measures of academic achievement

were not particularly sensitive to any change in instructional

approach [25]. Therefore, reported improvements in academic

achievement should not be dismissed lightly.

Note that while effect sizes are a common measure of the magnitude

of an improvement, absolute rather than relative values are

sometimes more telling. There can be an important difference between

results that are statistically significant and those that are significant

in absolute terms. For this reason, it is often best to find

both statistical and absolute measures of the magnitude of a reported

improvement before deciding whether it is significant.

As a final cautionary note for interpreting reported results, some

readers dismiss reported improvements from nontraditional instructional

methods because they attribute them to the Hawthorne

effect whereby the subjects knowingly react positively to any novel

intervention regardless of its merit. The Hawthorne effect is generally

discredited, although it retains a strong hold on the popular

imagination [26].

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***C. Summary***

There are pitfalls for engineering faculty hoping to pick up an article

or two to see if active learning works. In particular, readers

must clarify what is being studied and how the authors measure and

interpret what “works.” The former is complicated by the wide

range of methods that fall under the name of active learning, but

can be simplified by focusing on core elements of common active

learning methods. Assessing “what works” requires looking at a

broad range of learning outcomes, interpreting data carefully, quantifying

the magnitude of any reported improvement and having

some idea of what constitutes a “significant” improvement. This last

will always be a matter of interpretation, although it is helpful to

look at both statistical measures such as effect sizes and absolute values

for reported learning gains.

No matter how data is presented, faculty adopting instructional

practices with the expectation of seeing results similar to those reported

in the literature should be aware of the practical limitations

of educational studies. Educational studies tell us what worked, on

average, for the populations examined and learning theories suggest

why this might be so. However, claiming that faculty who adopt a

specific method will see similar results in their own classrooms is

simply not possible. Even if faculty master the new instructional

method, they can not control all other variables that affect learning.

The value of the results presented in Section IV of the paper is that

they provide information to help teachers “go with the odds.” The

more extensive the data supporting an intervention, the more a

teacher’s students resemble the test population and the bigger the

reported gains, the better the odds are that the method will work for

a given instructor.

Notwithstanding all of these problems, engineering faculty

should be strongly encouraged to look at the literature on active

learning. Some of the evidence for active learning is compelling and

should stimulate faculty to think about teaching and learning in

nontraditional ways.

**IV. THEEVIDENCEFORACTIVELEARNING**

Bonwell and Eison [1] summarize the literature on active learning

and conclude that it leads to better student attitudes and improvements

in students’ thinking and writing. They also cite evidence

from McKeachie that discussion, one form of active learning,

surpasses traditional lectures for retention of material, motivating

students for further study and developing thinking skills. Felder

et al. [27] include active learning on their recommendations for

teaching methods that work, noting among other things that active

learning is one of Chickering and Gamson’s “Seven Principles for

Good Practice” [28].

However, not all of this support for active learning is compelling.

McKeachie himself admits that the measured improvements of discussion

over lecture are small [29]. In addition, Chickering and

Gamson do not provide hard evidence to support active learning as

one of their principles. Even studies addressing the research base for

Chickering and Gamson’s principles come across as thin with respect

to empirical support for active learning. For example, Scorcelli

[30], in a study aimed at presenting the research base for Chickering

and Gamson’s seven principles, states that, “We simply do not

have much data confirming beneficial effects of other (not cooperative

or social) kinds of active learning.”

Despite this, the empirical support for active learning is extensive.

However, the variety of instructional methods labeled as active

learning muddles the issue. Given differences in the approaches labeled

as active learning, it is not always clear what is being promoted

by broad claims supporting the adoption of active learning. Perhaps

it is best, as some proponents claim, to think of active learning as an

approach rather than a method [31] and to recognize that different

methods are best assessed separately.

This assessment is done in the following sections, which look at

the empirical support for active, collaborative, cooperative and problem-

based learning. As previously discussed, the critical elements of

each approach are singled out rather than examining the effectiveness

of every possible implementation scheme for each of these distinct

methods. The benefits of this general approach are twofold.

First, it allows the reader to examine questions that are both fundamental

and pragmatic, such as whether introducing activity into the

lecture or putting students into groups, is effective. Second, focusing

on the core element eliminates the need to examine the effectiveness

of every instructional technique that falls under a given broad category,

which would be impractical within the scope of a single paper.

Readers looking for literature on a number of specific active learning

methods are referred to additional references [1, 6, 32].

***A. Active Learning***

We have defined the core elements of active learning to be introducing

activities into the traditional lecture and promoting student

engagement. Both elements are examined below, with an emphasis

on empirical support for their effectiveness.

**1) Introducing student activity into the traditional lecture:** On

the simplest level, active learning is introducing student activity into

the traditional lecture. One example of this is for the lecturer to

pause periodically and have students clarify their notes with a partner.

This can be done two or three times during an hour-long class.

Because this pause procedure is so simple, it provides a baseline to

study whether short, informal student activities can improve the effectiveness

of lectures.

Ruhl et al. [33] show some significant results of adopting this

pause procedure. In a study involving 72 students over two courses

in each of two semesters, the researchers examined the effect of interrupting

a 45-minute lecture three times with two-minute breaks

during which students worked in pairs to clarify their notes. In parallel

with this approach, they taught a separate group using a

straight lecture and then tested short and long-term retention of

lecture material. Short-term retention was assessed by a free-recall

exercise where students wrote down everything they could remember

in three minutes after each lecture and results were scored by the

number of correct facts recorded. Short-term recall with the pause

procedure averaged 108 correct facts compared to 80 correct facts

recalled in classes with straight lecture. Long-term retention was assessed

with a 65 question multiple-choice exam given one and a half

weeks after the last of five lectures used in the study. Test scores

were 89.4 with the pause procedure compared to 80.9 without

pause for one class, and 80.4 with the pause procedure compared to

72.6 with no pause in the other class. Further support for the effectiveness

of pauses during the lecture is provided by Di Vesta [34].

Many proponents of active learning suggest that the effectiveness

of this approach has to do with student attention span during lecture.

Wankat [35] cites numerous studies that suggest that student

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attention span during lecture is roughly fifteen minutes. After that,

Hartley and Davies [36] found that the number of students paying

attention begins to drop dramatically with a resulting loss in retention

of lecture material. The same authors found that immediately

after the lecture students remembered 70 percent of information

presented in first ten minutes of the lecture and 20 percent of information

presented in last ten minutes. Breaking up the lecture might

work because students’ minds start to wander and activities provide

the opportunity to start fresh again, keeping students engaged.

**2) Promoting Student Engagement:** Simply introducing activity

into the classroom fails to capture an important component of

active learning. The type of activity, for example, influences how

much classroom material is retained [34]. In “Understanding by

Design” [37], the authors emphasize that good activities develop

deep understanding of the important ideas to be learned. To do

this, the activities must be designed around important learning outcomes

and promote thoughtful engagement on the part of the student.

The activity used by Ruhl, for example, encourages students

to think about what they are learning. Adopting instructional practices

that engage students in the learning process is the defining feature

of active learning.

The importance of student engagement is widely accepted and

there is considerable evidence to support the effectiveness of student

engagement on a broad range of learning outcomes. Astin [38]

reports that student involvement is one of the most important predictors

of success in college. Hake [39] examined pre- and post-test

data for over 6,000 students in introductory physics courses and

found significantly improved performance for students in classes

with substantial use of interactive-engagement methods. Test

scores measuring conceptual understanding were roughly twice as

high in classes promoting engagement than in traditional courses.

Statistically, this was an improvement of two standard deviations

above that of traditional courses. Other results supporting the effectiveness

of active-engagement methods are reported by Redish et al.

[40] and Laws et al. [41]. Redish et al. show that the improved

learning gains are due to the nature of active engagement and not to

extra time spent on a given topic. Figure 1, taken from Laws et al.,

shows that active engagement methods surpass traditional instruction

for improving conceptual understanding of basic physics concepts.

The differences are quite significant. Taken together, the

studies of Hake et al., Redish et al. and Laws et al. provide considerable

support for active engagement methods, particularly for addressing

students’ fundamental misconceptions. The importance of

addressing student misconceptions has recently been recognized as

an essential element of effective teaching [42].

In summary, considerable support exists for the core elements of

active learning. Introducing activity into lectures can significantly

improve recall of information while extensive evidence supports the

benefits of student engagement.

***B. Collaborative Learning***

The central element of collaborative learning is collaborative vs.

individual work and the analysis therefore focuses on how collaboration

influences learning outcomes. The results of existing meta-studies

on this question are consistent. In a review of 90 years of research,

Johnson, Johnson and Smith found that cooperation improved learning

outcomes relative to individual work across the board [12]. Similar

results were found in an updated study by the same authors [13]

that looked at 168 studies between 1924 and 1997. Springer et al.

[43] found similar results looking at 37 studies of students in science,

mathematics, engineering and technology. Reported results for each

of these studies are shown in Table 1, using effect sizes to show the

impact of collaboration on a range of learning outcomes.

What do these results mean in real terms instead of effect sizes,

which are sometimes difficult to interpret? With respect to academic

achievement, the lowest of the three studies cited would move a

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***Figure 1. Active-engagement vs. traditional instruction for improving***

***students’ conceptual understanding of basic physics concepts***

***(taken from Laws et al., 1999)***

***Table 1. Collaborative vs. individualistic learning: Reported effect size of the improvement in different learning outcomes.***

student from the 50th to the 70th percentile on an exam. In absolute

terms, this change is consistent with raising a student’s grade from

75 to 81, given classical assumptions about grade distributions.\*

With respect to retention, the results suggest that collaboration reduces

attrition in technical programs by 22 percent, a significant

finding when technical programs are struggling to attract and retain

students. Furthermore, some evidence suggests that collaboration is

particularly effective for improving retention of traditionally underrepresented

groups [44, 45].

A related question of practical interest is whether the benefits of

group work improve with frequency. Springer et al. looked specifically

at the effect of incorporating small, medium and large amounts of

group work on achievement and found the positive effect sizes associated

with low, medium and high amount of time in groups to be 0.52,

0.73 and 0.53, respectively. That is, the highest benefit was found for

medium time in groups. In contrast, more time spent in groups did

produce the highest effect on promoting positive student attitudes,

with low, medium and high amount of time in groups having effect

sizes of 0.37, 0.26, and 0.77, respectively. Springer et al. note that the

attitudinal results were based on a relatively small number of studies.

In summary, a number of meta-analyses support the premise

that collaboration “works” for promoting a broad range of student

learning outcomes. In particular, collaboration enhances academic

achievement, student attitudes, and student retention. The magnitude,

consistency and relevance of these results strongly suggest that

engineering faculty promote student collaboration in their courses.

***C. Cooperative Learning***

At its core, cooperative learning is based on the premise that cooperation

is more effective than competition among students for

producing positive learning outcomes. This is examined in Table 2.

The reported results are consistently positive. Indeed, looking at

high quality studies with good internal validity, the already large effect

size of 0.67 shown in Table 2 for academic achievement increases

to 0.88. In real terms, this would increase a student’s exam

score from 75 to 85 in the “classic” example cited previously, though

of course this specific result is dependent on the assumed grade distribution.

As seen in Table 2, cooperation also promotes interpersonal

relationships, improves social support and fosters self-esteem.

Another issue of interest to engineering faculty is that cooperative

learning provides a natural environment in which to promote

effective teamwork and interpersonal skills. For engineering faculty,

the need to develop these skills in their students is reflected by the

ABET engineering criteria. Employers frequently identify team

skills as a critical gap in the preparation of engineering students.

Since practice is a precondition of learning any skill, it is difficult to

argue that individual work in traditional classes does anything to

develop team skills.

Whether cooperative learning effectively develops interpersonal

skills is another question. Part of the difficulty in answering that

question stems from how one defines and measures team skills.

Still, there is reason to think that cooperative learning is effective in

this area. Johnson et al. [12, 13] recommend explicitly training students

in the skills needed to be effective team members when using

cooperative learning groups. It is reasonable to assume that the opportunity

to practice interpersonal skills coupled with explicit instructions

in these skills is more effective than traditional instruction

that emphasizes individual learning and generally has no explicit instruction

in teamwork. There is also empirical evidence to support

this conclusion. Johnson and Johnson report that social skills tend

to increase more within cooperative rather than competitive or individual

situations [46]. Terenzini et al. [47] show that students report

increased team skills as a result of cooperative learning. In addition,

Panitz [48] cites a number of benefits of cooperative learning

for developing the interpersonal skills required for effective teamwork.

In summary, there is broad empirical support for the central

premise of cooperative learning, that cooperation is more effective

than competition for promoting a range of positive learning outcomes.

These results include enhanced academic achievement and a

number of attitudinal outcomes. In addition, cooperative learning

provides a natural environment in which to enhance interpersonal

skills and there are rational arguments and evidence to show the effectiveness

of cooperation in this regard.

***D. Problem-Based Learning***

As mentioned in Section II of this paper, the first step of determining

whether an educational approach works is clarifying exactly

what the approach is. Unfortunately, while there is agreement on

the general definition of PBL, implementation varies widely.

Woods et al. [16], for example, discuss several variations of PBL.

“Once a problem has been posed, different instructional methods may be

used to facilitate the subsequent learning process: lecturing, instructorfacilitated

discussion, guided decision making, or cooperative learning. As

part of the problem-solving process, student groups can be assigned to

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\*Calculated using an effect size of 0.5, a mean of 75 and a normalized grade distribution

where the top 10 percent of students receive a 90 or higher (an A) and the

bottom 10 percent receive a 60 or lower (an F).

***Table 2. Collaborative vs. competitive learning: Reported effect size of the improvement in different learning outcomes.***

complete any of the learning tasks listed above, either in or out of class. In the

latter case, three approaches may be adopted to help the groups stay on track

and to monitor their progress: (1) give the groups written feedback after each

task; (2) assign a tutor or teaching assistant to each group, or (3) create fully

autonomous, self-assessed “tutorless” groups.”

The large variation in PBL practices makes the analysis of its effectiveness

more complex. Many studies comparing PBL to traditional

programs are simply not talking about the same thing. For

meta-studies of PBL to show any significant effect compared to traditional

programs, the signal from the common elements of PBL

would have to be greater than the noise produced by differences in

the implementation of both PBL and the traditional curricula.

Given the huge variation in PBL practices, not to mention differences

in traditional programs, readers should not be surprised if no

consistent results emerge from meta-studies that group together

different PBL methods.

Despite this, there is at least one generally accepted finding that

emerges from the literature, which is that PBL produces positive

student attitudes. Vernon and Blake [19] looking at 35 studies from

1970 to 1992 for medical programs found that PBL produced a significant

effective size (0.55) for improved student attitudes and

opinions about their programs. Albanese and Mitchell [20] similarly

found that students and faculty generally prefer the PBL approach.

Norman and Schmidt [18] argue “PBL does provide a

more challenging, motivating and enjoyable approach to education.

That may be a sufficient raison d’etre, providing the cost of the implementation

is not too great.” Note that these and most of the results

reported in this section come from studies of medical students,

for whom PBL has been widely used. While PBL has been used in

undergraduate engineering programs [49, 50] there is very little

data available for its effectiveness with this population of students.

Beyond producing positive student attitudes, the effects of PBL

are less generally accepted, though other supporting data do exist.

Vernon and Blake [19], for example, present evidence that there is a

statistically significant improvement of PBL on students’ clinical

performance with an effect size of 0.28. However, Colliver [22]

points out that this is influenced strongly by one outlying study with

a positive effect size of 2.11, which skews the data. There is also evidence

that PBL improves the long-term retention of knowledge

compared to traditional instruction [51–53]. Evidence also suggests

that PBL promotes better study habits among students. As one

might expect from an approach that requires more independence

from students, PBL has frequently been shown to increase library

use, textbook reading, class attendance and studying for meaning

rather than simple recall [19, 20, 53, 54].

We have already discussed the problems with meta-studies that

compare non-uniform and inconsistently defined educational interventions.

Such studies are easily prone to factors that obscure results.

The approach for handling this difficulty with active, collaborative

and cooperative learning was to identify the central element

of the approach and to focus on this rather than on implementation

methods. That is more difficult to do with PBL since it is not clear

that one or two core elements exist. PBL is active, engages students

and is generally collaborative, all of which are supported by our previous

analysis. It is also inductive, generally self-directed, and often

includes explicit training in necessary skills. Can one or two elements

be identified as common or decisive?

Norman and Schmidt [18] provide one way around the difficulty

by identifying several components of PBL in order to show how

they impact learning outcomes. Their results are shown in Table 3,

taken directly from Norman and Schmidt using the summary of

meta-studies provided by Lipsey and Wilson [17]. The measured

learning outcome for all educational studies cited by Lipsey and

Wilson was academic achievement.

Norman and Schmidt present this table to illustrate how different

elements of PBL have different effects on learning outcomes.

However, the substantive findings of Table 3 are also worth highlighting

for faculty interested in adopting PBL because there seems

to be considerable agreement on what works and does not work in

PBL.

Looking first at the negative effects, there is a significant negative

effect size using PBL with non-expert tutors. This finding is

consistent with some of the literature on helping students make the

transition from novice to expert problem solvers. Research comparing

experts to novices in a given field has demonstrated that becoming

an expert is not just a matter of “good thinking” [42]. Instead,

research has demonstrated the necessity for experts to have both a

deep and broad foundation of factual knowledge in their fields. The

same appears to be true for tutors in PBL.

There is also a small negative effect associated with both selfpaced

and self-directed learning. This result is consistent with the

findings of Albanese and Mitchell [20] on the effect of PBL on test

results. In seven out of ten cases they found that students in PBL

programs scored lower than students in traditional programs on

tests of basic science. However, in three out of ten cases, PBL

students actually scored higher. Albanese and Mitchell note that

these three PBL programs were more “directive” than others,

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***Table 3. Effect sizes associated with various aspects of problem-based learning.***

indicating that this element might be responsible for the superior

exam performance for students in those programs. Therefore, faculty

might be advised to be cautious about the amount of self-direction

required by students in PBL, at least with regard to promoting

academic achievement as measured by traditional exams.

Looking at what seems to work, there are significant positive effect

sizes associated with placing students in small groups and using

cooperative learning structures. This is consistent with much of the

literature cited previously in support of cooperative learning. While

PBL and cooperative learning are distinct approaches, there is a

natural synergy that instructors should consider exploiting. That is,

real problems of the sort used in PBL require teams to solve effectively.

At the same time, the challenge provided by realistic problems

can provide some of the mutual interdependence that is one of

the five tenets of cooperative learning.

Table 3 also shows that positive results come from instruction in

problem solving. This is consistent with much of the advice given

by proponents of problem-based learning [55]. While practice is

crucial for mastering skills such as problem solving, greater gains are

realized through explicit instruction of problem solving skills. However,

traditional engineering courses do not generally teach problem

solving skills explicitly. Table 3 suggests that faculty using PBL

consider doing just that.

In conclusion, PBL is difficult to analyze because there is not

one or two core elements that can be clearly identified with student

learning outcomes. Perhaps the closest candidates for core elements

would be inductive or discovery learning. These have been shown

by meta-studies to have only weakly positive effects on student academic

achievement [56, 57] as measured by exams. This might explain

why PBL similarly shows no improvement on student test

scores, the most common measure of academic achievement.

However, while no evidence proves that PBL enhances academic

achievement as measured by exams, there is evidence to suggest

that PBL “works” for achieving other important learning outcomes.

Studies suggest that PBL develops more positive student attitudes,

fosters a deeper approach to learning and helps students retain

knowledge longer than traditional instruction. Further, just as cooperative

learning provides a natural environment to promote interpersonal

skills, PBL provides a natural environment for developing

problem-solving and life-long learning skills. Indeed, some evidence

shows that PBL develops enhanced problem-solving skills in

medical students and that these skills can be improved further by

coupling PBL with explicit instruction in problem solving. Similarly,

supporting arguments can be made about PBL and the important

ABET engineering outcome of life-long learning. Since selfdirected

learning and meta-cognition are common to both PBL

and life-long learning, a logical connection exists between this desired

learning outcome and PBL instruction, something often not

true when trying to promote life-long learning through traditional

teaching methods.

**IV. CONCLUSIONS**

Although the results vary in strength, this study has found support

for all forms of active learning examined. Some of the findings,

such as the benefits of student engagement, are unlikely to be controversial

although the magnitude of improvements resulting from

active-engagement methods may come as a surprise. Other findings

challenge traditional assumptions about engineering education and

these are most worth highlighting.

For example, students will remember more content if brief activities

are introduced to the lecture. Contrast this to the prevalent content

tyranny that encourages faculty to push through as much material

as possible in a given session. Similarly, the support for collaborative

and cooperative learning calls into question the traditional assumptions

that individual work and competition best promote achievement.

The best available evidence suggests that faculty should structure

their courses to promote collaborative and cooperative

environments. The entire course need not be team-based, as seen by

the evidence in Springer et al. [43], nor must individual responsibility

be absent, as seen by the emphasis on individual accountability in cooperative

learning. Nevertheless, extensive and credible evidence suggests

that faculty consider a nontraditional model for promoting academic

achievement and positive student attitudes.

Problem-based learning presents the most difficult method to

analyze because it includes a variety of practices and lacks a dominant

core element to facilitate analysis. Rather, different implementations

of PBL emphasize different elements, some more effective

for promoting academic achievement than others. Based on the literature,

faculty adopting PBL are unlikely to see improvements in

student test scores, but are likely to positively influence student attitudes

and study habits. Studies also suggest that students will retain

information longer and perhaps develop enhanced critical thinking

and problem-solving skills, especially if PBL is coupled with explicit

instruction in these skills.

Teaching cannot be reduced to formulaic methods and active

learning is not the cure for all educational problems. However, there

is broad support for the elements of active learning most commonly

discussed in the educational literature and analyzed here. Some of

the findings are surprising and deserve special attention. Engineering

faculty should be aware of these different instructional methods

and make an effort to have their teaching informed by the literature

on “what works.”

**ACKNOWLEDGMENTS**

The author would like to thank Richard Felder for his thoughtful

critique of this work and for many similar pieces of advice over the

past several years. The National Science Foundation through Project

Catalyst (NSF9972758) provided financial support for this project.

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