ENGINEERING MANAGEMENT TRAINING: *COMPARING EXPERIENTIAL VERSUS LECTURE METHODS OF INSTRUCTION*

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While many studies have compared passive and active instructional methods, none provides statistical evidence that one method is clearly superior. When the subject matter to be taught is technical in nature, however, the experiential method has been shown to be more effective in terms of both student reactions and learning.

The environment faced by most organizations today is characterized by increasing dependence on technology, whether that technology is a product of the organization or the tool it uses to compete in the marketplace. In addition to the emergence of technology as a dominant consideration in the strategy of organizations, the pace of technological change has accelerated to the point that technical obsolescence is a concern that affects both products and people. In 1994 the Motorola Corporation estimated that the knowledge of the average engineer becomes obsolete in 2 to 5 years (Motorola, 1995).

Furthermore, competition has become global in nature, increasing the pressures on organizations to be both technically agile and to be economically efficient producers. In this environment of complex technologies, rapid technical obsolescence, and global competition, organizations have increasingly accepted the idea that education and training are key to the ability of the organization to compete in the global economic environment.

Training is a major commitment for technically focused firms today, and it has become a big business. Motorola, for example, affords each of its 132,000 employees one week of training each year (Motorola, 1995), and, according to one estimate (Dipoye, Smith, and Howell, 1994), U.S. corporations having 100 or more employees spent $43.2 billion for training during 1991. With this level of commitment in mind, it becomes particularly important that training be conducted as effectively as possible, and that the instructional methods used be those that contribute most to improving the job performance of the student.

This article describes a study that made a side-by-side comparison of instructional methods used to teach two large groups of students attending the Advanced Program Management Course (APMC) at the Defense Systems Management College (DSMC). One group was taught the systems engineering management portion of the course using lecture and discussion as the primary teaching method, while the second group was taught experientially using a hands-on design project. The learning objectives of the two courses were identical and the student groups evaluated were very homogeneous. This appeared to be an excellent opportunity to conduct a controlled study in order to investigate the impact of teaching methods on learning outcomes. Given the substantial commitment made by business and government to education and training, the results of this investigation could be important in determining the nature of training for students in future courses.

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RELATED LITERATURE

Perhaps the best known and most comprehensive approach to the assessment of training was developed by Kirkpatrick (1977). His model comprised four discrete and progressive levels of evaluation: student reactions, learning achieved, transfer of changed behaviors to the workplace, and results achieved in the workplace. Most evaluation does not go beyond assessment of student reactions (Dipoye, Smith, and Howell, 1994) and appears to be based on the assumption that, if the student leaves the course with a positive attitude regarding the training, then there will be positive results in other measures of effectiveness.

Research indicates that this assumption is likely to be a poor one. In a study evaluating the relationships among the different levels in the Kirkpatrick model, Alliger and Janak (1989) found no significant relationship between student reactions to training and the higher levels—learning, transfer to the workplace, or results achieved. This makes intuitive sense; the course rated favorably by students may not be the one that provides useful learning. On the other hand, Alliger and Janak found a positive relationship among the higher levels, indicating that learning, once achieved, will likely result in the transfer of lessons learned to the workplace, and subsequently to improved results in the workplace.

The fact that there is positive linkage among the higher three levels, but no relationship between student reaction and learning, suggests that learning is the critical indicator of course effectiveness; learning is the linchpin. If the student learns, the course is likely to result in a positive change at all levels of effectiveness. Others, such as Landy (1987) and Maier (1973), have observed that, while the prevailing assumption has been that attitudes influence behavior, for this to be true requires a confluence of other factors, such as experience and motivation. Evaluation that stops at the assessment of student reaction too often provides little in the way of useful information regarding the probability that the training results in learning or that the training will carry over into the workplace.

Adult learning theory, as espoused by Knowles (1980) and others, implies that adults will learn and retain more when they take an active role, participate more, and use multiple senses in the learning process. A number of research efforts have been conducted with the objective of evaluating the extent to which teaching methods influence learning, but few statistically significant conclusions have been recorded. According to Rachal (1994), "...advocacy of andragogy as a superior strategy for facilitating adult learning does not seem to be borne out by the existing empirical studies... ."

Table 1 summarizes a number of studies that have compared teaching methods. All compared various participative and experiential methods with a control group taught using more passive methods. Significantly, none established a statistical difference in the learning achieved using one method in preference to the other. Campbell noted in his later work (1988) that analyses performed in this topic area are increasingly well structured and rigorous; however, even in more recent studies, there is little statistical evidence that experiential methods are superior to more passive methods.

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In spite of this consistent pattern of failure to find differences in the results achieved between instructional methods in various types of training courses, the present study was structured specifically to compare the effectiveness of alternative methods. Many of the studies reviewed seemed to have one or more problems:

- In some cases the differentiation between "participative" and "nonparticipative" conditions was nebulous.
- In many cases the samples were quite small, so the power to discriminate was lessened.
- Where the samples were reasonably large, the research was conducted in environments (universities, corporations) that are apt to be subject to a great deal of outside interference (Walleri and Japely, 1986).

The numbers of subjects available at DSMC, the homogeneity of the groups who attend courses (Table 2), and the fact that students are largely isolated from their work and outside interference suggested that the environment would be ideal for a

Table 1. Related Studies of Comparative Teaching Methods

Author	Group	N	Methods Compared	Instruments	Analytic Methods	Results (Learning)
Bretz and Thompsett (1992)	Kodak Corp. MRP Training	180	Lecture vs. integration	Survey, pretest, learning	ANOVA Correlation posttest	No difference *P* = .01
Carr (1982)	University (Economics)	26	Lecture vs. case study	Pretest, posttest	T-test, ANOVA	No difference *P* = .05
Carter (1995)	University (physical training)	36	Lecture vs. case study	Survey, posttest (only)	MANOVA	No difference *P* = .10
James (1991)	Adult (education)	31	Lecture vs. case study	Pretest, posttest	ANOVA T-test Regression	No difference *P* = .05
Merrill (1995)	Adult medical (cardiac)	37	Lecture vs. self-study	Pretest, posttest	ANCOVA	No difference *P* = .05
Thoms and Klein (1994)	Adult (hospital management)	64	Nonparticipation vs. participation	Survey, multiple tests	ANOVA Correlation Chi-Square	No difference *r* = .16
Ward (1993)	Navy (medical)	300	Nonparticipation vs. participation	Survey, posttest (only)	T-test, ANOVA	Learning not assessed
Welch (1990)	University students (business)	181	Lecture vs. active methods	Pretest, posttest	ANOVA	No difference *P* = .05
White (1995)	University students (tech)	112	Lecture vs. computer-aided training	Survey, pretest, posttest	ANOVA	No difference *P* = .10

comparison of teaching methods in conditions where those methods were likely to be the primary determinant of differences observed in performance. This is an issue of particular interest since many organizations are moving rapidly to implement curricula that are experiential and hands-on (Parkinson, 1994; Raelin and LeBien, 1993) rather than lecture-based and theoretical, in spite of the lack of empirical research findings that support that trend.

METHOD

SUBJECTS AND METHODS COMPARED

The APMC is a training course for Department of Defense (DoD) program managers, conducted at DSMC. Those attending the course are selected from that portion of the DoD acquisition workforce who either hold senior management positions (program managers, deputy program managers, functional managers, and division heads) in program offices, or who are being prepared for such positions.

While they take the course, they are relieved from their assigned jobs, are relocated to DSMC, and are expected to attend classes daily in various topics related to project management.

APMC 95-1 was taught the engineering management portion of the course using lecture-discussion methods with limited exercises. APMC 96-1 entered a year later, but, rather than lecture, this group was taught by integrating the instruction with a design project. The students in APMC 96-1 were required to plan, design, build, and then test a vehicle based on a set of performance requirements issued at the beginning of the course. All engineering management instruction was woven into, and was related to, the design project. APMC 95-1 was the control group, and APMC 96-1 was the treatment group for purposes of this study.

Each offering of the APMC included approximately 420 students—a representative mix of military and civilian employees in DoD research and development

Table 2. Demographics of Control and Treatment Groups

Attribute	APMC 95-1	APMC 96-1
Affiliation		
Air Force	29.7%	30.5%
Army	28.9%	25.0%
Navy/Marines	28.6%	32.9%
Other	12.9%	11.6%
Highest education level		
Masters/Ph.D.	69.4%	71.4%
Bachelors/other	30.6%	28.6%
Education type		
Technical	48.6%	47.1%
Management/other	51.4%	52.9%
Military	55.3%	50.7%
Civilian	44.7%	49.3%
Female attendees	13.6%	16.9%
Acquisition experience (years)	9.5	10.8
DoD experience (years)	15.5	17.4
Sample total	360[a]	420

[a] Two sections (60 students) were excluded from the APMC 95-1 control group, because they were used to pilot the techniques that were later used in teaching the APMC 96-1 course.

activities. In addition, a few employees of defense industry corporations typically attend each class offering. Table 2 compares the demographics of the two groups involved in this study. The homogeneity of the students who attend these courses is remarkable—they are of similar ages (typically 35 to 40 years old); they tend to have similar educational and experience backgrounds, and they are similar in civilian/military mix as well as in service affiliation.

Each class was divided into 14 sections of 30 students. Section assignment was a stratified random process; subgroups were established proportionally by service affiliation (Army, Navy, Air Force), then assignment to sections was random. The result was a distribution that was proportionally representative of the entire class in terms of service or industry affiliation, and which was random in terms of assignment of individuals to sections.

Sections received the same program of instruction based on an established curriculum with learning objectives that were identical both among sections and between the two class groups. Each section was taught by an assigned instructor. The 12 sections in the control group were taught by eight instructors (four of whom taught two sections); the 14 sections of the treatment group were taught by 12 instructors (5 of whom had taught the control group). Neither instructors nor students were aware that student data would be analyzed for the purposes of this study. A concern that the control group (95-1) might have treated the course with less seriousness (since this was the last offering of the format in use at the time) were resolved by comparing the end of course comprehensive exam scores of APMC 95-1 with previous classes. Their scores were essentially equal to those of their predecessors, indicating no lessening of effort or learning on their part.

INSTRUMENTS

This study evaluated the effectiveness of the training offered in terms of the first

1. Are you employed as a
    a. Government civilian
    b. Military
    c. Contractor
    d. None of the above

2. Highest level of formal education achieved
    a. Bachelor's degree
    b. Master's degree
    c. Doctoral/Ph.D.
    d. Other (specify)________________

Figure 1. Sample Items from Pretest Demographic Survey

two levels of the Kirkpatrick model, and consequently measurement of student reactions and learning were key. The collection of data was handled through administration of pretest and posttest instruments.

Pretest. The pretest included a test of knowledge in the engineering management domain and a survey of demographic factors. The domain knowledge test is discussed in more detail below. The demographic questionnaire surveyed employment and educational background, experience, and previous training prior to exposure to the APMC course. An example of two items on the demographic survey is shown in Figure 1.

Posttest. The posttest consisted of a questionnaire that measured student reactions to the course and a second test of knowledge in engineering management. Both were administered at the final training session. The questionnaire included five questions and also provided for subjective student comments. Three of the questions addressed the extent to which students found the course of instruction informative, enjoyable, and characterized by reasonable workloads; these were the questions viewed to best reflect student reactions to the course, as described by Kirkpatrick. The remaining items dealt with preferences for hands-on versus lecture and the future usefulness of the training in the work environment. Responses were given in numerical form using a seven-point Likert scale. Figure 2 shows a sample question.

Domain knowledge test. The domain knowledge test was the means for measuring learning. A panel of subject matter experts in engineering management from DSMC evaluated all questions proposed for content validity. This panel consisted of six experienced systems engineering managers who were teaching in the APMC, all of whom were Level III members of the Defense Acquisition Work Force. Questions were formally scored on the extent to which they satisfactorily addressed the learning objectives with which they were associated. These learning objectives were derived from the set of competencies required of the systems engineering management subcourse in the APMC.

The internal reliability of the instruments was evaluated over a period of several months by testing them on several groups of students who were attending

I found the systems engineering course material informative.

Strongly disagree ... Strongly agree

|——|——|——|——|——|——|

1 4 7

Figure 2. Sample Item from Posttest Student Reaction Questionnaire

DSMC short courses in systems engineering management. In terms of experience levels and other key variables such as educational backgrounds, the attendees at Level III short courses are comparable to the attendees at APMC. The major difference is that the attendees at the specialized short courses in engineering management tend to be predominantly from the technical disciplines and to hold technical management positions, while the APMC includes a more balanced mix of managers from various functional areas.

Tests were administered using the split-half procedure. As experience was gained through repeated testing in succeeding courses, adjustments were made in the content and mix of the tests based on item analyses. The reliability was finally demonstrated to be 0.930. As an additional check, the entire question set was also administered as a single exam, and the reliability was calculated using the Kuder-Richardson (KR 20) formula. The results of that calculation indicated that the mean reliability of all split half combinations is 0.83, still well within the bounds normal to skills and competency based tests in use.

The full question set was divided into halves with demonstrated reliability 0.93. In their final form the two tests (pretest and posttest) were each 15 questions that tested student knowledge at the application level and which had been demonstrated to do so equally. An example from one of those tests is shown in Figure 3.

Procedure. The pretest instrument was administered to both the control and treatment groups during their first lesson in the systems engineering subcourse. The posttest was administered to both groups

As your program approaches CDR, your systems engineer informs you that, in his/her estimation, the design is about 60% complete. Assuming that his/her estimate is correct, you should (choose one):

a. Continue as planned and hold the CDR as scheduled. In today's environment, design maturity is not an issue for government program managers.

b. Hold the CDR as scheduled. There are minimal risks associated with early CDRs, since designs continue to mature until well after CDR is completed.

c. Delay holding the CDR until the design is substantially complete. A design should be 85–90% complete before the CDR is conducted.

d. Delay the CDR until the contractor completes and delivers the system specification for government review.

Figure 3. Sample Domain Knowledge Test Item

Table 3. Two-Sample *t* Test for Pretest[a]

Class	N	Mean	SD	t
APMC 95-1	359	57.2	15.9	1.02[b]
APMC 96-1	407	58.4	16.2	

[a] H_o: APMC 95-1 = APMC 96-1.
[b] P = .30.

at the end of that course. Taken together, the two provided the means to compare knowledge levels between and within groups, both before and after exposure to the engineering management course of training. They also provided the means to relate knowledge of engineering management concepts and principles to demographic factors, and, finally, they measured student reactions to the training received. The administration of these two instruments completed the data collection for the conclusions drawn here.

This was a pretest-posttest control group experimental study. The span of time between the pretest and posttest administration was 10 weeks. Pretest-posttest interaction was controlled in this case by the timing of the two tests and by using different questions in the pretest and posttest. The differences in the pretest and posttest, in combination with a span of more than two months between measurements, was considered adequate to guard against pretest-posttest interaction.

Results of the Analyses

Initial Knowledge Levels

While the data in Table 2 indicate strong similarity between the groups, it was important to determine whether or not the two sample groups were equal with respect to the level of knowledge upon entry to the course. The results (Table 3) indicate that the initial knowledge level, as shown by mean pretest scores of the two groups, was equal (P =?.05). Initial equality between groups made more supportable a conclusion that the differences observed later could be attributed to exposure to the training, rather than to differences that may have existed at the outset of the experiment.

The analysis then turned to investigation of hypotheses that were structured to parallel the first two levels of the Kirkpatrick model (1977). These were that students would react more favorably to a curriculum taught using experiential methods, and that students would learn more from curriculum taught using experiential methods.

Student Reactions

Student reaction data were collected using the posttest questionnaire described earlier. The three variables used as indicators of student reactions and associated statements were:

- Informed: I found the engineering management course informative.

- Enjoyed: I enjoyed the engineering management course.
- Workload: The course covered too much material for the time allotted.

Analytic results indicate that APMC 96-1, the class taught using experiential methods, believed that the class was more informative, enjoyed the course more, and perceived the workload to be less oppressive (Table 4). This last finding is interesting in that the requirement to design, fabricate, and test vehicles appeared to have represented a considerably increased workload over that associated with the course taught using lecture-discussion methods, yet the students indicated that they perceived the workload to be less.

Narrative reactions were also solicited from the students of the two courses. The results, while more subjective, corroborated the analytic results of the *t* tests in that the comments of APMC 95-1 indicated less satisfaction than did APMC 96-1.

LEARNING

A number of studies (e.g., Bretz and Thompsett, 1992) have concluded that exposure to experiential instruction will result in student reactions that are more positive than those elicited from classes exposed to the more traditional lecture and discussion approach to teaching. The results reported above confirm and strengthen these findings.

Theory leads one to expect that the experiential methods would produce superior results, not only in student reactions, but also in learning. To measure learning, this study used the combination of the

Table 4. Two Sample *t* Test for Student Reactions

Variable	N	Mean (Scale of 1 to 7)	SD	*t*
Informed				
APMC 95-1	321	4.67	1.30	–4.12[a]
APMC 96-1	393	5.12	1.57	
Enjoyed				
APMC 95-1	322	4.51	1.41	–5.01[a]
APMC 96-1	393	5.09	1.64	
Workload				
APMC 95-1	322	3.41	1.48	4.78[a]
APMC 96-1	392	2.88	1.44	

[a] $P = .01$.

Table 5. Student Comments on Engineering Management Course

Category	APMC 95-1 (%)	APMC 96-1 (%)
Satisfied (commented positively)	10	14
Dissatisfied (commented negatively)	17	15
Satisfied/neutral (commented generally, but neither favorably nor unfavorably)	13	17
Neutral (did not comment)	60	54

pretest and posttest to measure knowledge levels at the beginning of training and at the completion. Analysis of covariance was used to adjust observed posttest scores, controlling for differences observed in pretest results. We used *t* tests to measure both the extent to which each instructional method resulted in positive learning (pretest vs. posttest) and to measure the extent to which one method produced more learning than the other (posttest vs. posttest). Table 6 gives the results of those tests (pretest scores are repeated for convenience).

These tests indicate that both lecture and experiential methods produced positive learning. The tests furthermore indicate that the experiential method produced a higher level of knowledge as indicated by posttest scores. This statistically supports the theoretical hypothesis that experiential training produces an improved level of learning; however, the differences measured were smaller than might have been expected or hoped for. More will be said on this topic later.

Relationship between Student Reactions and Learning

Alliger and Janak (1989) found no significant relationship between student reactions and learning. This study presented an opportunity to evaluate whether or not that same lack of relationship was in evidence in this study, as well. Since the demographics (Table 2) and initial analysis of pretest scores indicated that the two groups involved could reasonably be considered to represent a single underlying population, the two were combined into a single large group for purposes of this analysis.

Table 6. Domain Knowledge Test Scores

Group	Pretest Mean	Posttest Mean	Posttest Mean (Adj.)	Posttest SD	*t* Test (Pre-Post)	*t* Test (Post-Post)
APMC 95-1	57.2	73.2	73.4	16.6	–12.67[a]	–3.93[a]
APMC 96-1	58.4	77.8	77.7	14.1	–17.89[a]	
[a] $P = .01$.						

Table 7.
Multiple Regression—Student Reactions and Pretest on Posttest Score[a]

Predictors	Dependent Variable, Posttest Score				
	ß	SD	Seq. SS	*t*	*P*
Constant	64.332	3.367		19.1	0.000
Informed	–0.594	0.849	188.6	–0.70	0.484
Enjoyed	0.360	0.800	5,13.7	0.45	0.653
Workload	–1.754	0.392	6,596.3	–4.48	0.000
Pretest	0.301	0.037	16,374.1	8.34	0.001

[a] R-Sq (Adj.) = 11.9%.

Using the variables "enjoyed," "informed," and "workload" (described earlier) as the indicators of student reactions, we performed a multiple regression on posttest score. While "workload" was significant (P = .05), these variables together explained little of the total variance in posttest scores, leading to the conclusion that student reactions are essentially unrelated to learning, and thus supporting the Alliger and Janak observation.

As a further check, pretest scores were then added as an independent variable. Table 7 shows the result of the regression analysis. While the addition of pretest scores improved the model somewhat, the coefficient of determination remained quite low, indicating that the outcome of the course of instruction was primarily explained by factors other than either pretesting or student reactions. There was a moderate correlation (r = .33) between pretest and posttest scores, i.e., those who score well on the pretest tend to score well on the posttest and vice versa.

OTHER FACTORS THAT INFLUENCE INITIAL LEVELS OF KNOWLEDGE

The pretest instrument included a survey that requested information regarding the student's job status, educational level, educational specialty, previous work experience, and professional training. The final part of the study involved analysis of the extent to which pretest score was influenced by these categorical factors. Pretest scores were used as an indicator of typical knowledge levels among the acquisition workforce population at large. The data were grouped to enable analysis of factors, each with multiple states as shown in Table 8. Factorial ANOVA was used for the analysis.

Education type, years of program management experience, and the nature of training courses taken previously were most significant. Somewhat surprising was the finding that the nature of current job held (technical or nontechnical) and the interval since attendance at training courses did not produce significant differences.

Table 8. Effect of Categorical Factors on Pretest Performance

Factor	States Addressed	Adj. SS	F	*P*
Employment status	Military or civilian	121.1	0.52	0.470
Education level	Graduate versus other	968.3	4.18	0.041
Type of education	Technical versus nontechnical	4,313.9	18.61	0.000
Current job	Technical versus nontechnical	114.6	0.49	0.482
Management experience	Years of experience	2,581.9	11.14	0.001
Gender	Male or female	672.1	2.90	0.089
Previous training courses	None, general, or functionally specific	3,338.5	14.41	0.000
Interval	Years since last training	14.9	0.06	0.800
Error	df = 693	160,602.5		

Since the type of educational background (technical or nontechnical) that the individual possessed produced very significant differences in test scores, it might have been expected that the type of job currently held would produce similar differences. Formal technical education appears to convey a broader, more integrative level of knowledge that contributes to the individual's ability to organize and control resources to accomplish a technical objective (engineering management), while holding a technical job did not. The nature of technical work is often highly specialized and relatively narrowly focused, which may explain the fact that those with technical jobs did not score significantly better on the pretest.

The nature of previous training courses attended deserves comment, also. The prerequisite training courses attended by students at APMC tend to fall into two general categories: those that address program management in general by exposing the student to relatively short subcourses in a variety of disciplines (of which engineering management is one), and those that are focused on a specific management discipline (such as engineering management or contract management).

This study found that students exposed to multidisciplinary general management courses did not perform significantly differently on the engineering management pretest from those who had not attended previous training. On the other hand, those who had attended training that was functionally specialized to teach engineering management performed significantly better on the pretest than all other subgroups, including those who had attended general management courses and those who had attended no training at all.

In addition to these primary effects, the interactions among factors provided several interesting insights. For example, the results indicated that technical management experience can go far to overcome any disadvantages associated with nontechnical formal education. The relative advantages (in terms of pretest score) associated with technical education are largely isolated to those who have little or no experience. When both had experience in program management offices, technically educated and nontechnically educated students essentially performed equally.

> "This study found the differences in learning produced by the two methods investigated to be smaller than expected...."

In this sense, education can be viewed as a means of achieving the equivalent of a level of experience prior to actually entering the technical management environment. Similarly, the study did not indicate that the time interval elapsed since training was influential in determining pretest scores. When the interaction of the elapsed interval and experience was evaluated, the results indicated that experience more than accounted for any losses due to the passage of time since training.

Discussion and Conclusions

These data support the hypothesis that students react more favorably to instruction that uses more experiential, active approaches to learning. While this and more traditional approaches to teaching result in positive learning experiences for the student, the work documented here further indicates that students learn more when experiential teaching methods are used in training. These findings in combination should encourage designers of technical training to structure courses that feature hands-on learning where theoretical and conceptual topics are reinforced by experiences gained during the training. Too many courses relegate applications and lessons learned through experience to the post-training period.

This study found the differences in learning produced by the two methods investigated to be smaller than expected; other studies have found no conclusive differences at all. There is a possibility that the problem has been in the instruments used to measure learning. When an identical instrument is used to measure knowledge levels between groups (as was the case in this study where the same pretests and posttests were used for each of the two groups), comparisons are naturally restricted to the knowledge levels measured by the instrument. In the case of most objective tests, knowledge measured is limited to levels two or three of the Bloom taxonomy (1956).

It is possible that the instruments used in this study did not capture the full extent of learning in the experiential course of training. For example, students synthesized designs, evaluated them, fabricated models based on the designs, and then evaluated the extent to which the products met original requirements. The tests used, however, did not address the higher levels of learning associated with this activity. This study was able to demonstrate statistical differences between methods, due in some part to the large size of the control and treatment groups involved (nominally 360 and 420).

Future studies should take care to make certain that measurements of results fully account for all of the learning involved. If they do, more conclusive support for the use of experiential methods may be found. Additional research in this area would be useful, since the current literature is largely inconclusive on the topic of differences in learning outcomes as a function of instructional methods used.

This research also supports earlier work that found little or no relationship between student reactions to training and the learning that students achieve. Few organizations evaluate training at all; and many courses evaluate training only at the level of student reactions, assuming that positive reactions will result in positive learning and transfer of training to the workplace. That is apparently not a well-justified assumption. The evidence is conclusive that training evaluation must include an assessment of learning to be of value as an indicator of training effectiveness. Training is too costly and too important to the future of both organizations and their people to tolerate less.

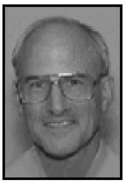
Finally, this study addressed the extent to which various factors influence technical management knowledge levels in general. Education type (technical or otherwise), previous management experience, and the nature of previous training appear to be most influential. Surprisingly, neither the interval since most recent training nor the nature of the job currently held appeared to have substantial impact on knowledge levels. This has a number of interesting implications. For example, engineers generally need additional education or management experience to be good technical managers; they do not acquire technical management knowledge naturally as a by-product of their technical expertise. Another observation was that training, to be most effective, needs to be functionally focused. Courses that address too broad an array of functional topics will likely prove ineffective at training in any of them.

These findings must be balanced against certain limitations, including those associated with the instruments used to evaluate the learning achieved through the use of experiential methods. It is possible that the results documented did not account for all the learning achieved.

Another consideration is that the domain knowledge investigated is specific to the engineering management models that are common to the Department of Defense and to much of the U.S. aerospace industry as reflected in current industry standards, such as the Electronic Industries Association (EIA, 1994) and Institute of Electrical and Electronics Engineers (IEEE, 1994) standards for systems engineering management. But the findings may not be applicable to nontechnical fields or to environments in which the standard models for engineering management do not apply.

"Another observation was that training, to be most effective, needs to be functionally focused."

In spite of these limitations, this work extends previous analytic work and confirms theoretical work in an area where empirical results are sparse. It also illuminates several areas—associated with training individuals to perform as engineering managers—that merit further study.



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REFERENCES

Alliger, G. M., & Janak, E. A. (1989). Kirkpatrick's levels of training criteria: Thirty years later. *Personnel Psychology, 42,* 331–342.

Bloom, B. S. (1956). Taxonomy of educational objectives: The classification of educational objectives (Book 1). *The cognitive domain.* New York: Longman.

Bretz, R. D. Jr., & Thompsett, R. E. (1992). Comparing traditional and integrative learning methods in organizational training programs. *Journal of Applied Psychology, 77*(6), 941–951.

Campbell, J. P. (1988). Training design for performance improvement. In J. P. Campbell and R. J. Campbell (Ed.), *Productivity in organizations.* San Francisco: Jossey-Bass Publishers.

Carr, N. J. (1982). An evaluation of the use of case studies in economics at advanced levels in schools. In *Research papers in economics education.* London: London University, Institute of Education.

Carter, L. D. (1995). *Effectiveness of case-based method versus traditional lecture in the retention of athletic training knowledge.* Doctoral dissertation, Oregon State University.

Dipoye, R. L., Smith, C. S., & Howell, W. C. (1994). *Understanding industrial and organizational psychology: An integrated approach.* Fort Worth, TX: Harcourt Brace College Publishers.

Electronic Industries Association. (1994). Interim Standard 632, Systems Engineering. Washington, DC: EIA Engineering Publications Office.

Institute of Electrical and Electronics Engineers. (1994). IEEE 1220: Standard for Application and Management of the Systems Engineering Process. New York: IEEE Standards Department.

James, F. R. (1991). An analysis of case-based instruction in teacher preparation classroom management training. Doctoral dissertation, University of Virginia.

Kirkpatrick, D. L. (1977). Evaluating training programs: Evidence versus proof. *Training and Development, 31,* 9–12.

Knowles, M. S. (1980). *The modern practice of adult education: From pedagogy to andragogy.* New York: Cambridge Co.

Landy, F. J. (1987). *Psychology: Science of people.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Maier, N. F. (1973). *Psychology in industrial organizations.* Boston: Houghton Mifflin.

Merrill, P. A. (1995). *A comparison of two teaching methods in basic cardiac life support training and education.* Master's thesis, Grand Valley State University.

Motorola Corporation. (1995). *1994 Annual Report.* Schaumburg, IL: Motorola Corporation Corporate Offices.

Parkinson, G. (1994, October). Hands on learning: The new wave in Ch.E. education. *Chemical Engineering,* 45–49.

Rachal, J. R. (1994). Andragogical and pedagogical methods compared: A review of the experimental literature. Paper published by U.S. Department of Education, Office of Educational Research and Improvement, Washington, DC.

Raelin, J. A., & LeBien, M. (1993). Learn by doing. *HR Magazine,* 61–70, February.

Thoms, P., & Klein, H. J. (1994). Participative and evaluative outcomes in management training. *Human Resources Development Quarterly,* 5, (Spring): 27–39.

Ward, F. P. (1993) *An investigation of the effects instructional strategies have on student attitudes.* Doctoral dissertation, The George Washington University.

Walleri, R. D., & Japely, S. M. (1986). *Student intent, persistence, and outcomes.* Paper presented at the 26th Annual Forum of the Association for Institutional Research, Orlando, FL.

Welch, B. D. (1990). *Effects of method of instruction on student achievement, student description of teaching, and the interaction of student motivation, cognition strategies, and resource management strategies in an undergraduate business class.* Doctoral dissertation, Texas A&M University.

White, M. J. (1995). *Relationship between teaching method and student achievement in technical college introduction to microcomputer courses.* Doctoral dissertation, Auburn University.