Major Shifts in Engineering Education and their Implications

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ASEE ERM Distinguished Lectures – First Eleven

1980	Burrhus F. Skinner	The Future of Technology and Education
1981	Robert F. Mager	Academic Applications of Educational Methods Developed in Industry
1982	Wilbert J. McKeachie	Student Anxiety, Learning and Achievement
1983	Samuel N. Postlewait	Using Science and Technology to Teach Science and Technology
1985	Fred F. Keller	Testimony of an Educational Reformer
1986	Moshe F. Rubinstein	Rational and Imaginative Thinking in the Computer Age
1987	Benjamin S. Bloom	A Search for Methods of Instruction as Effective as One-on-One Tutoring
1988	Donald A. Schon	Marrying Applied Science and Artistry in Engineering Education
1989	William G. Perry, Jr.	Students' Evolution of their Definition of Knowledge and Their Expectations of Teachers
1990	Frederick Reif	Engineering Human Knowledge and Thinking: Opportunities for Better Engineering Education
1991	K. Patricia Cross	College Teaching: What Do We Know About It?

https://erm.asee.org/conferences/distinguished-lecturers/

Session Layout

BIG IDEAS

Major Shifts in Engineering Education

Implications – personal and national

Interactive Session

Reflection and Dialogue

Formulate-Share-Listen-Create

Shifts in Engineering Education

- What were/are they?
- What did we learn/are we learning about advancing engineering education?
- What are the implications for the future of engineering education?

Major Shifts in Engineering Education (~1912-2012)

1. Engineering science - a shift from hands-on and practical emphasis to engineering science and analytical emphasis
2. Outcomes and accreditation - a shift to outcomes-based education and accreditation
3. Engineering design - a shift to emphasizing engineering design
4. Social-behavioral sciences - a shift to applying education, learning, and social-behavioral sciences research
5. ICC technologies - a shift to integrating information, computational, and communications technology in education

Froyd, J., Wankat, P. & Smith, K.A. (2012) Smith, K.A. & Chavela, R. (2021) Smith, K.A. (2024))

Studies of Engineering Education

Mann Report (1918)	Wickenden Report (1930)
Hammond Report (1940)	Grinter Report (1955)
“Goals” Report (1968)	Green Report (1994)
Educating the Engineer of 2020 (2005)	Innovation with Impact (2012)

Mann Report (1918) Principal Points

- Waste occurring in educational efforts arising from lack of coordination
- Regulation of admission – At present sixty percent of those who enter fail to graduate
- Packed curriculum and lock-step course sequences
- Necessity of a common core
- Emphasize the problems of values and costs

Global Calls for Reform

K-12 Engineering

Research-based Transformation

Reflection and Dialogue

Individually reflect on **major shifts in your engineering education thinking and/or practices** and prepare to talk with a neighbor. Think/write for about 1 minute.

Discuss with your neighbor for about 2 minutes

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Shift 1 - Engineering Science and Analytical Emphasis

Theory

(Study grounded in theory/conceptual framework)

Research that
makes a difference . . .
in theory and practice

Research

(Appropriate design and methodology)

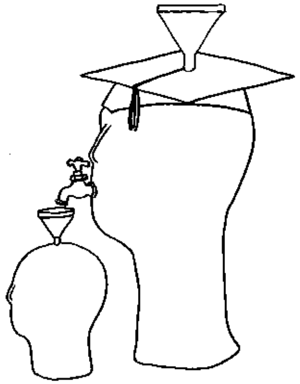
Practice

(Implications for practice)

Engineering Education IMPLICATION:

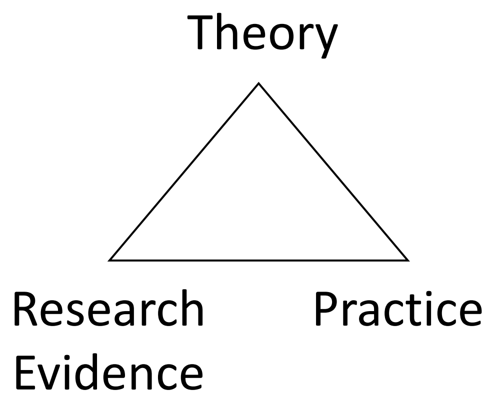
Theory and research matter.

Personal Implication of Shift 1 - a shift from hands-on and practical emphasis to engineering science and analytical emphasis



First Teaching Experience

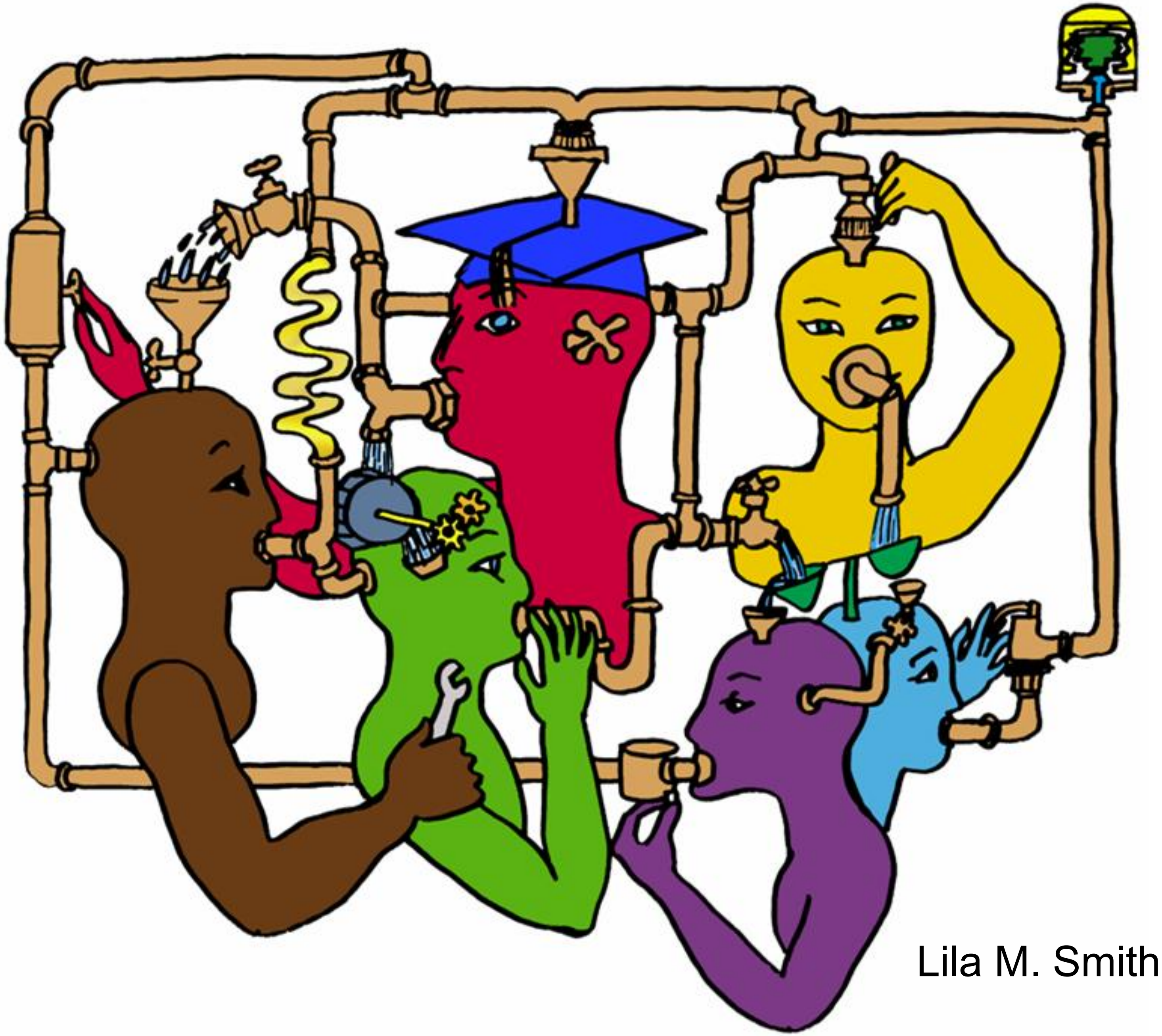
- Practice – Third-year course in metallurgical reactions – thermodynamics and kinetics
- Theory – ?
- Research – ?



Lila M. Smith

University of Minnesota College of Education – Social, Psychological and Philosophical Foundations of Education

- Statistics, Measurement, Research Methodology
- Assessment and Evaluation
- Learning and Cognitive Psychology
- Knowledge Acquisition, Artificial Intelligence, Expert Systems
- Development Theories
- Motivation Theories
- History and Philosophy of Education
- Small Group Procedures for Personal and Organizational Change
- Social psychology of learning – student – student interaction



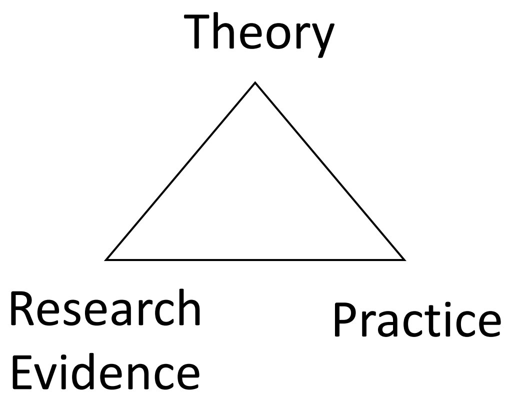
Lila M. Smith

Cooperative Learning

Theory – Social Interdependence – Lewin – Deutsch – Johnson & Johnson

Research – Randomized Design Field Experiments

Practice – Formal Teams/Professor's Role



Cooperative Learning Introduced to Engineering – 1981

Smith, K.A., Johnson, D.W. and Johnson, R.T., 1981. The use of cooperative learning groups in engineering education. In L.P. Grayson and J.M. Biedenbach (Eds.), *Proceedings Eleventh Annual Frontiers in Education Conference*, Rapid City, SD, Washington: IEEE/ASEE, 26–32.

[Smith, K.A., Sheppard, S.D., Johnson, D.W. and Johnson. R.T. 2005. Pedagogies of Engagement: Classroom-based Practices (cooperative learning and problem-based learning). Journal of Engineering Education, 94: 87–101]()

Structuring Learning Goals To Meet the Goals of Engineering Education

Karl A. Smith,
David W. Johnson, and Roger T. Johnson
University of Minnesota

The growing concern about engineering education in the United States has been the subject of many recent editorials and articles.* They point to the deteriorating quality of engineering and science education, the lack of adequate preparation in mathematics and science on the part of high school graduates, the shortage of engineers, and, especially, the shortage of college teachers of engineering. Unless corrective measures are taken, it may be more difficult in the coming years to achieve the goals of engineering education and

the development of implementation skills for converting knowledge into action.

Interpersonal competence requires the development of the cognitive, affective and behavioral prerequisites for working with others to perform a task.[1] Among the skills required are communication, constructive conflict management, interpersonal problem solving, joint decision making and perspective-taking skills. Interpersonal competence is becoming increasingly important for engineers due to the tremendous technical

the interaction between society ar technology.

Needs of Engineering Graduates

Many studies have been con ducted on engineering educatio since it began at West Point in 1792 and these have been well summa rized.[2] The earliest study (by Mann in 1918) called for a return to the basics; each of the subsequent ones emphasized diversity and a broad education,[3] and their general findings have been summarized by Cheit[4] in the following three statements:

1) There is renewed concern that, despite many efforts, engineering education is not yet incorporating what is called the "humanistic-social," "liberal," or "general" parts of the students' education.

2) Engineering education must be more broadly applied, that is, engineers must build bridges between science and the needs of society.

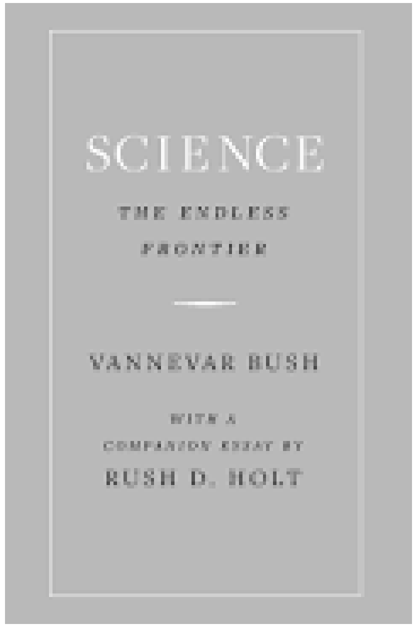
3) Engineers must be made decision makers, since, despite the growing importance of engineering to American life, engineers have not taken a correspondingly important part in the decision-making process.

The recommendations of these studies are similar and recurrent, but the need for change in engineering education remains. Currently, there

JEE December 1981

Broader Implications of Shift 1

Vannevar Bush



1945

IMPLICATIONs:

National Science Foundation – 1950

National Academy of Engineering - 1964

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Shift 2 – Outcomes-based Education and Accreditation

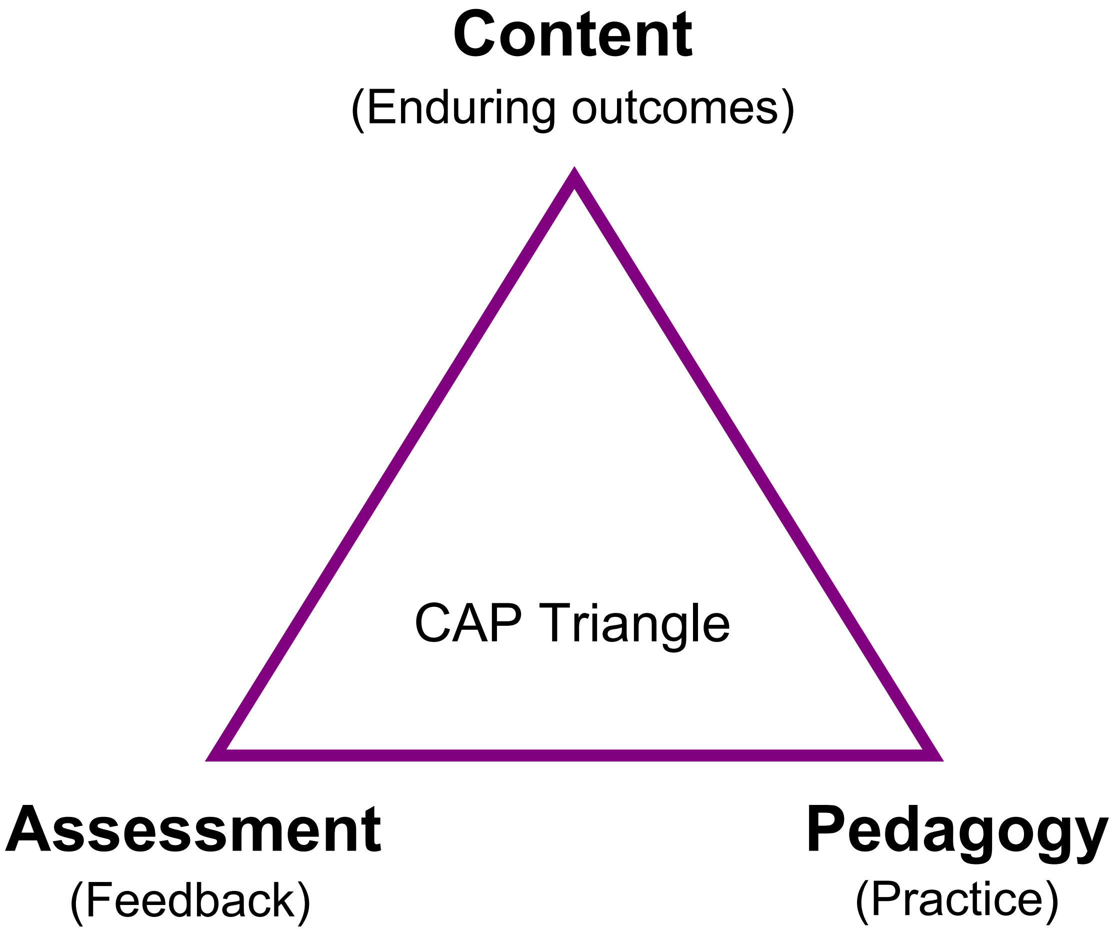
ABET Engineering Criteria 2000

Criterion 3. Program Outcomes and Assessment

Engineering programs must demonstrate that their graduates have

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to **design** and conduct experiments, as well as to analyze and interpret data
(c) an ability to **design** a system, component, or process to meet desired needs
(d) an ability to **function on multi-disciplinary teams**
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

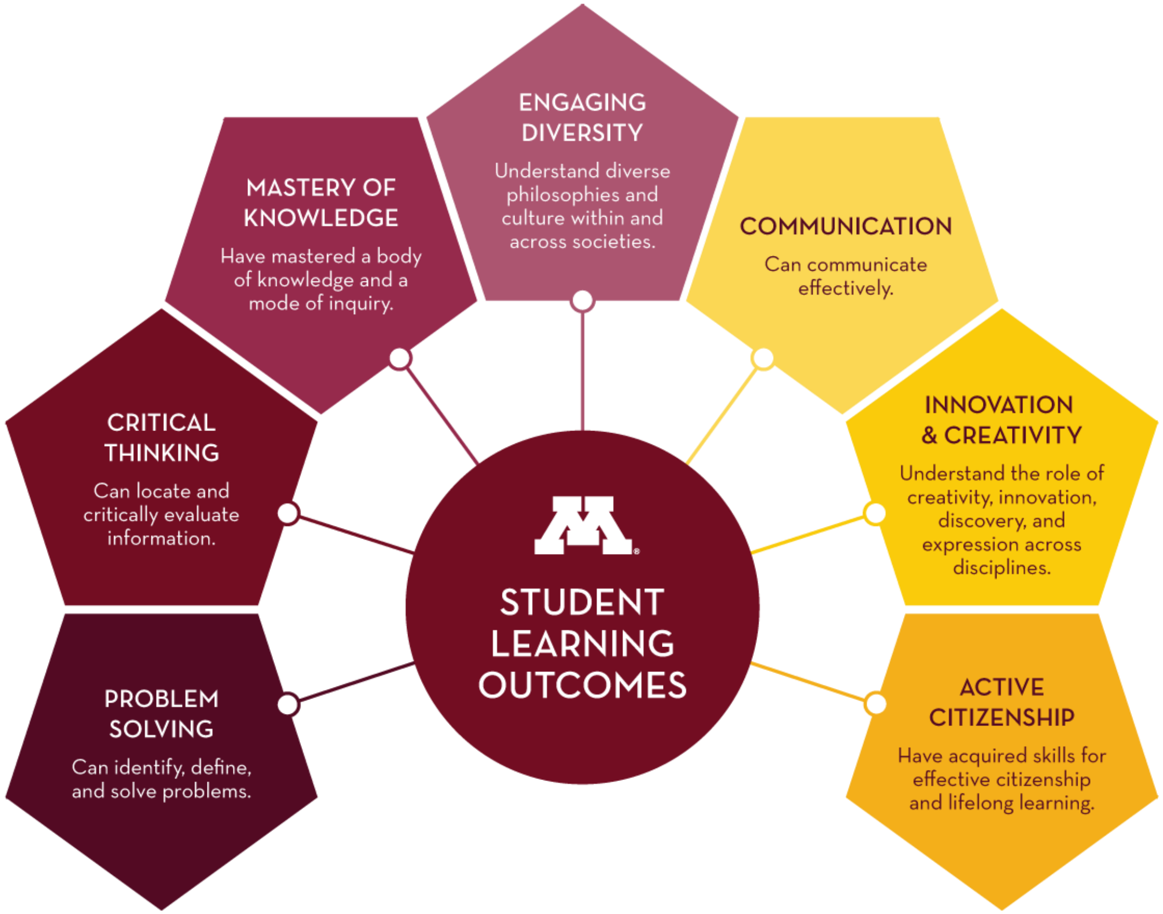
Implication of Shift 2

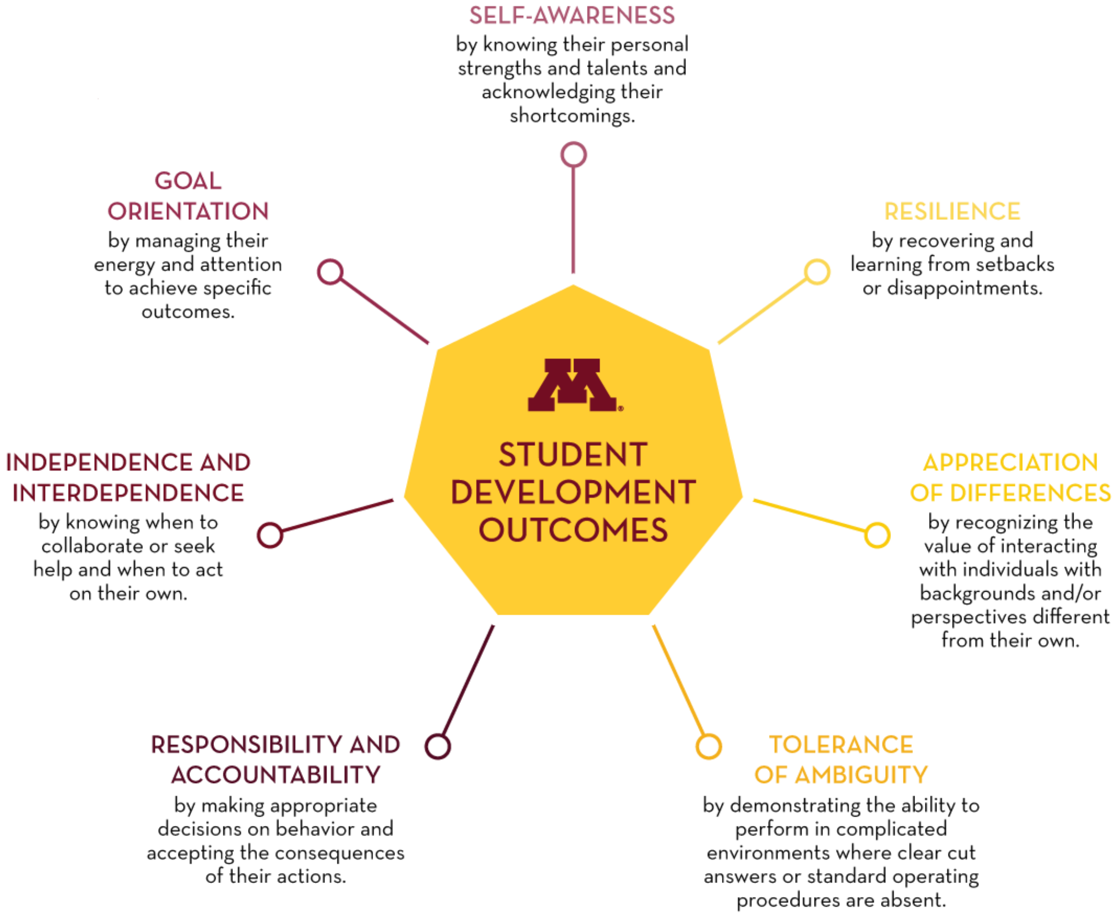


IMPLICATION:

Identifying and articulating enduring outcomes is a critical part of effective course design.

Learning and Development Outcomes UMN





https://slo.umn.edu

Assessment at the Course Level

Knowledge Survey

Classroom Assessment (minute paper)

Mid-Term Review

Student Management Team

Peer Review

Minute Paper
(Classroom Assessment Technique)

What was the most useful or meaningful thing you learned during this session?

What question(s) remain uppermost in your mind as we end this session?

What was the "muddiest" point in this session?

Give an example or application

Explain in your own words . . .

Angelo, T.A. & Cross, K.P. 1993. Classroom assessment techniques: A handbook for college teachers. San Francisco: Jossey Bass.

Mid-Term Review

U of M: Course Evaluations - Microsoft Internet Explorer

https://eval.umn.edu/showTemplates.pl?templateid=1060

UNIVERSITY OF MINNESOTA

University Course Evaluations

Sample Form

Student Evaluation of Teaching (SET) - Early Semester Form B

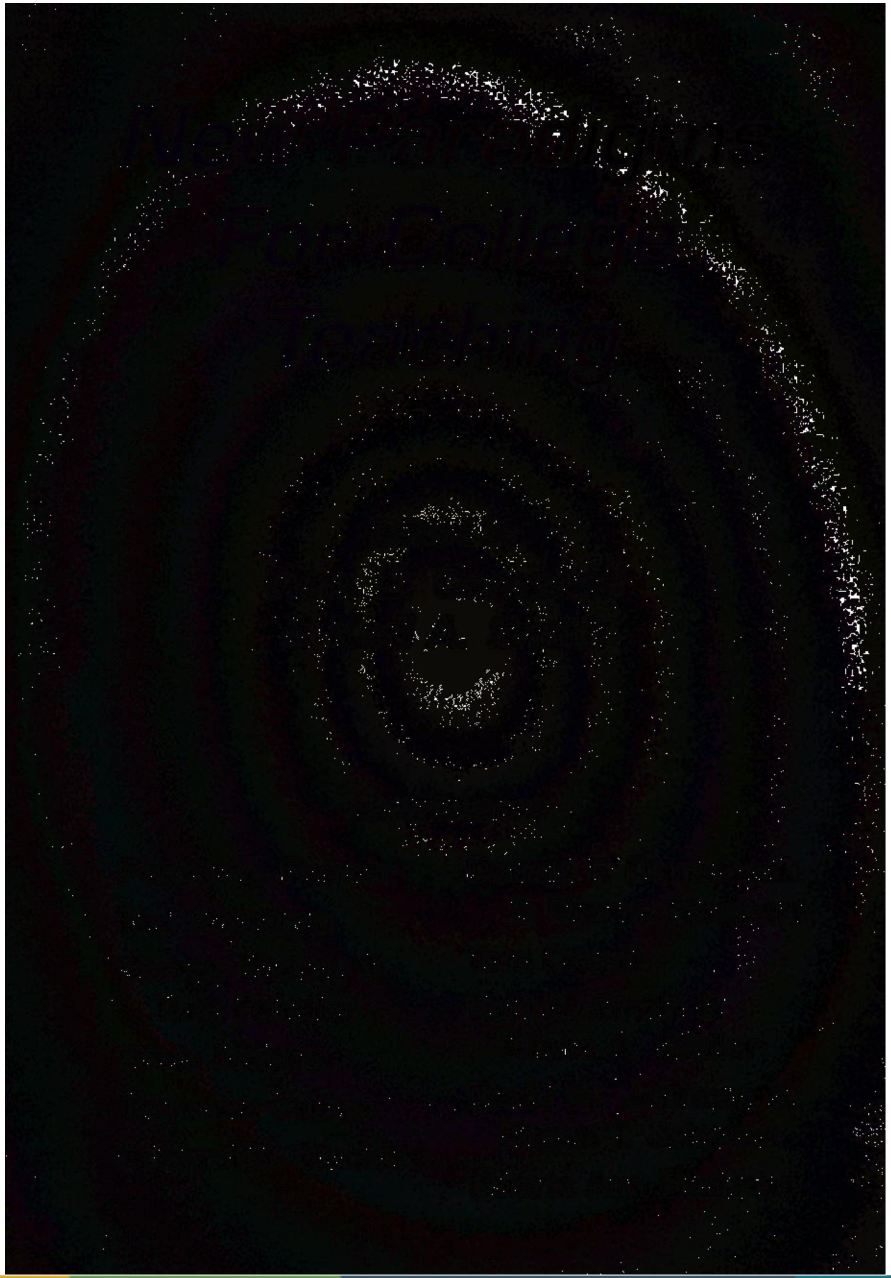
The purpose of this survey is to provide the instructor with information that may help to improve this class. The results will be reported only to the instructor: they will not be used in tenure, promotion, and salary decisions. Your thoughtful written comments are especially requested.

Unsatisfactory (1)	*Marginal* (2)	*Fairly Good* (3)	*Very Good* (4)	*Excellent* (5)	
○	○	○	○	○	**Your understanding of what is expected of you in this course.**
○	○	○	○	○	**The instructor's clarity in presenting or discussing course material.**
○	○	○	○	○	**The instructor's use of examples or illustrations.**
○	○	○	○	○	**The instructor's encouragement of students to think about course material.**
○	○	○	○	○	**The instructor's ability to speak clearly and audibly.**
○	○	○	○	○	**The instructor's success in getting you interested or involved.**
○	○	○	○	○	**The instructor's availability to answer questions or provide help.**
○	○	○	○	○	**The instructor's respect and concern for students.**
○	○	○	○	○	**Your comfort in asking questions or expressing an opinion in class.**
○	○	○	○	○	**Helpfulness of feedback on assignments or class work.**
○	○	○	○	○	**Degree to which evaluation procedures (e.g. exams, quizzes) measure your knowledge and understanding.**

Much less (1)	*Less* (2)	*About the same* (3)	*More* (4)	*Much more* (5)	
○	○	○	○	○	**How much does the amount of work required in this class compare with that in similar classes you have taken?**

Chapter 8: Student Management Teams: The Heretic's Path to Teaching Success by Edward B. Nuhfer

Wm. Campbell & Karl Smith. *New Paradigms for College Teaching*. Interaction Books, 1997.



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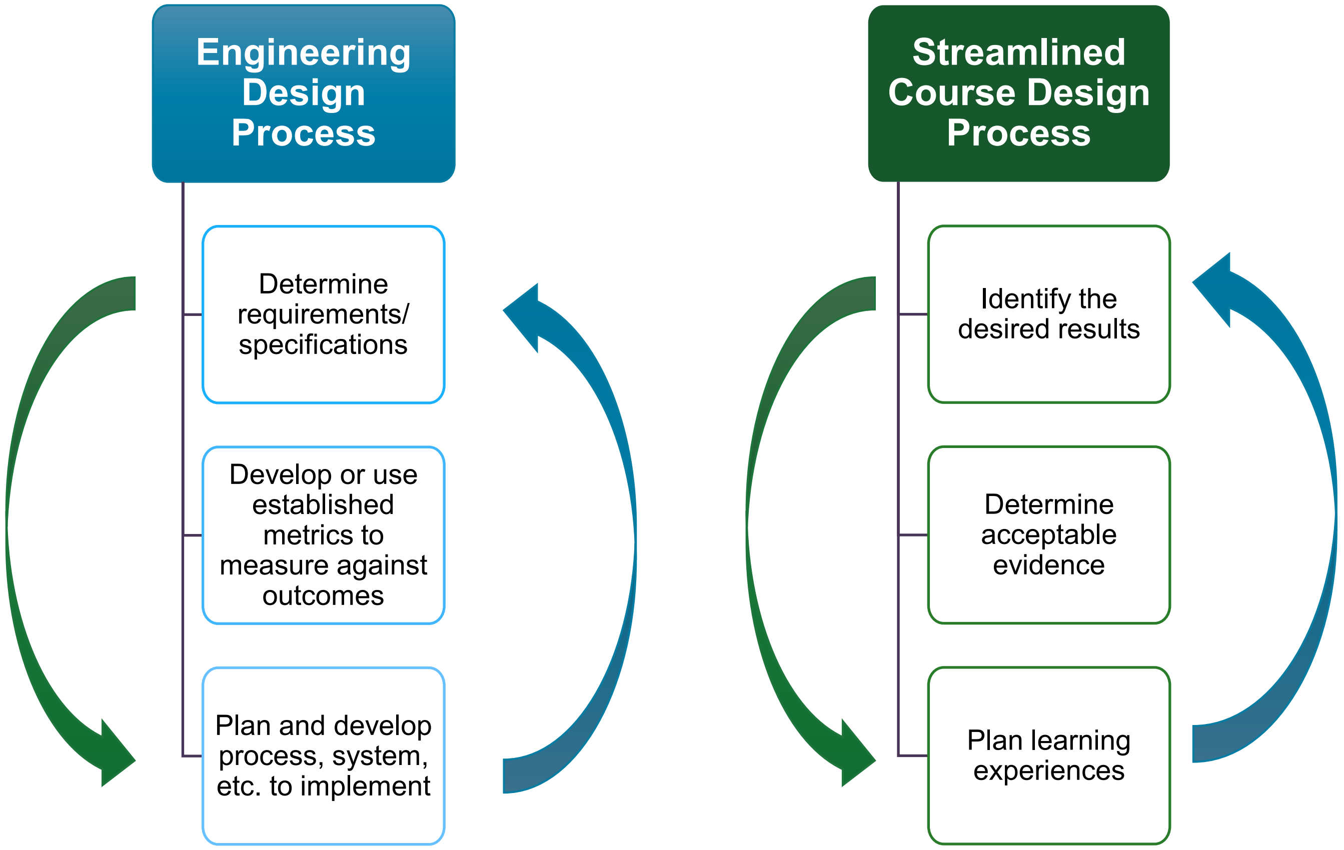
Implications of Shift 2 – Emphasis on Engineering Design



IMPLICATION:

Embracing the engineering design process for course design makes sense.

James Duderstadt
Nuclear Engineering Professor
Former Dean, Provost and President
University of Michigan

“ It could well be that faculty members of the twenty-first century college or university will find it necessary to set aside their roles as teachers and instead become **designers of learning experiences, processes, and environments.**”

Reflection and Dialogue

Individually reflect on the first three **major shifts in engineering education.** How have they influenced your engineering education **thinking and/or practices?**

1. **Engineering science**
2. **Outcomes and Accreditation**
3. **Engineering Design**

Think/write for about 1 minute.

Discuss with your neighbor for about 2 minutes

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Education, Learning and Social-Behavioral Sciences

How People Learn

Interactive Learning

Personal and Academic Support

Psychological Safety

IMPLICATIONS:

Applying what we know about learning is essential:

Cognitive Domain

Affective Domain

Education, Learning and Social-Behavioral Sciences

How People Learn

Interactive Learning

IMPLICATIONS:

Applying what we know about learning is essential:

Cognitive Domain

Learning Requires…

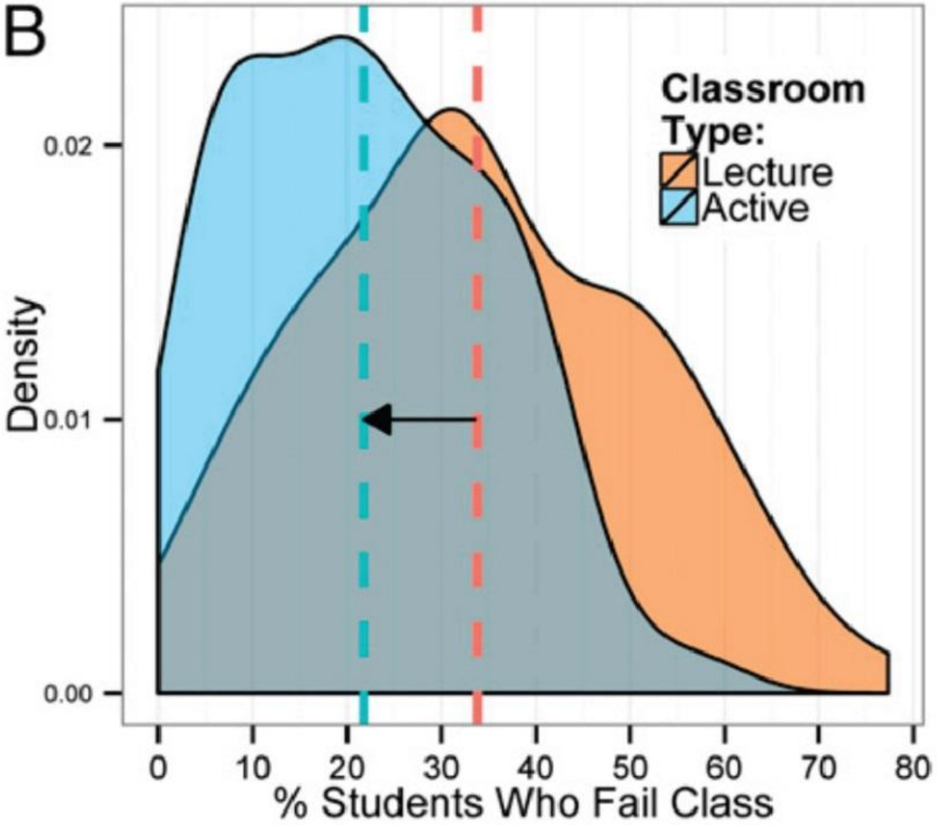
Deliberate	Distributed	Practice
▪ Cognitive load (bandwidth) ▪ Reflection ▪ Processing	▪ Repetition over time ▪ Multiple input modes	▪ Attentive ▪ Constructive ▪ Interactive

I-C-A-P Framework

Interactive	> Constructive	> Attentive ~~(Active)~~	> Passive
Substantive dialogue on the same topic, not ignoring a partner's contribution	Producing outcomes that go beyond presented information	Doing something physically Paying attention	
Guided-construction	Self-construction	Engaging activities	
Joint creation processes	Creation processes	Attending processes	

See: Chi (2009)

Interactive Learning = Reduced Failure Rate



See: Freeman, et.al. (2014)

Engineering Thermodynamics
PLSG earned statistically almost **one full letter grade higher** than students in the no-treatment group; they were also statistically **more likely to have passed the course** and to have graduated with their degree approximately one year after taking it

Milcarek, R., et.al. (2025) The Impact of Peer-led Study Groups on Student Achievement in a Gateway Engineering Thermodynamics Course. https://advances.asee.org/wp-content/uploads/vol13/Issue1/13.1_4_Brunhaver.pdf

Bloom’s Distribution

If we are effective in our instruction, the distribution of achievement should be very different from the normal curve. In fact, we may even insist that our educational efforts have been unsuccessful to the extent that the distribution of achievement approximates the normal distribution. (p. 52)

Bloom, B. S., Madaus, G. F., and Hastings, J. T., Evaluation to improve learning. New York, NY: McGraw-Hill, 1981.

Education, Learning and Social-Behavioral Sciences

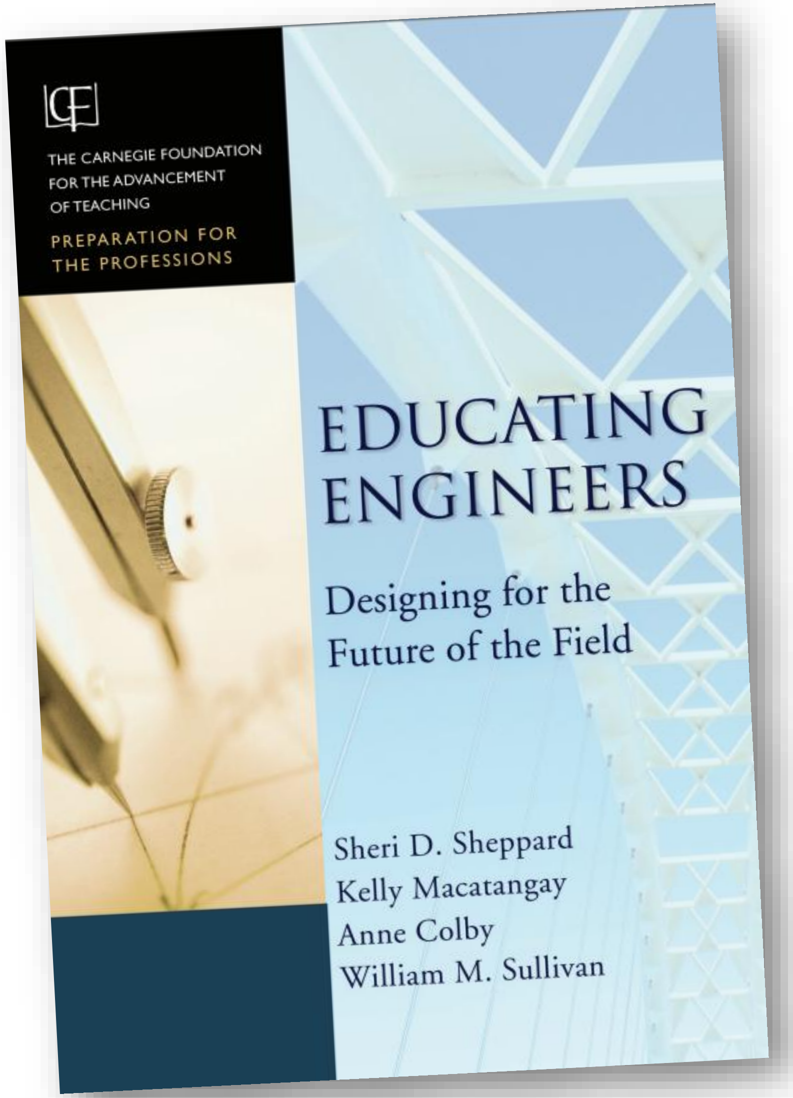
IMPLICATIONS:

Applying what we know about learning is essential:

Personal and Academic Support

Psychological Safety

Affective Domain



Sullivan (2005) – The Three Apprenticeships of Professional Education

1. **Head** – intellectual/cognitive development
2. **Hand** – tacit body of skills shared by competent practitioners
3. **Heart** – ways of thinking and habits of mind, including the values and attitudes shared by the professional community

Student Support is Essential

Academic Support

Classmates and faculty:

Help students succeed academically.

Personal Support

Classmates and faculty:

Care about and are personally committed to the **well-being** of each student.

The greater the social support, the greater the academic challenges may be.

Creative Tension Between Challenge and Security

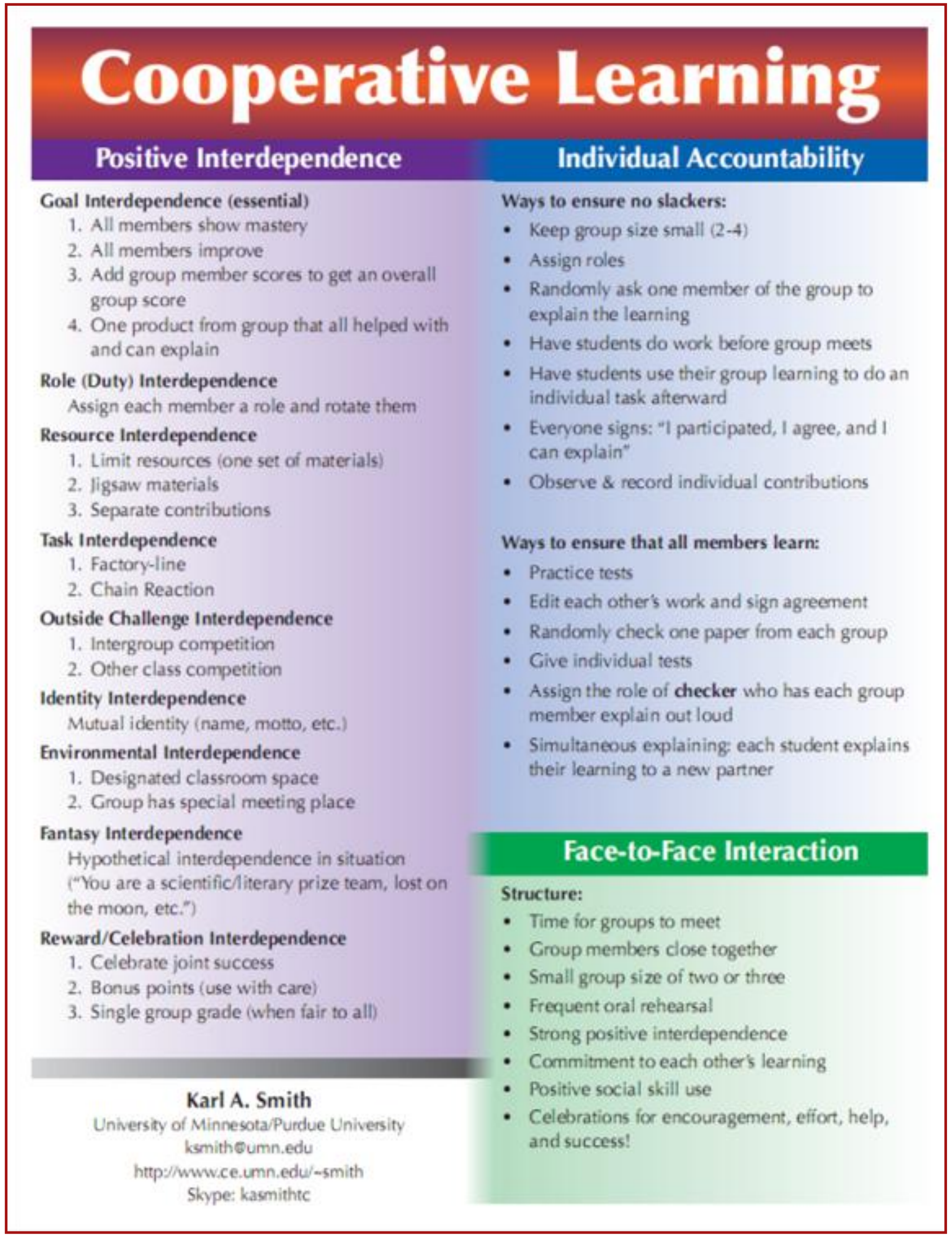
	ACCOUNTABILITY FOR MEETING DEMANDING GOALS: LOW	ACCOUNTABILITY FOR MEETING DEMANDING GOALS: HIGH
PSYCHOLOGICAL SAFETY: HIGH	**Comfort Zone** People really enjoy working with one another but don't feel particularly challenged. Nor do they work very hard.	**Learning Zone** The focus is on collaboration and learning in the service of high-performance outcomes.
PSYCHOLOGICAL SAFETY: LOW	**Apathy Zone** People tend to be apathetic and spend their time jockeying for position.	**Anxiety Zone** People fear to offer tentative ideas, try new things, or ask colleagues for help

See: Edmonson (2008)

See also: Pelz and Andrews (1966); Pelz (1976)

Cooperative Learning: An Evidence-Based Practice for Interactive Learning

Cooperative learning is instruction that involves people working in teams to accomplish a common goal, under conditions that involve both *positive interdependence* (all members must cooperate to complete the task) and *individual and group accountability* (each member is accountable for the complete final outcome).



Cooperative Learning

Positive Interdependence

Goal Interdependence (essential)
1. All members show mastery
2. All members improve
3. Add group member scores to get an overall group score
4. One product from group that all helped with and can explain

Role (Duty) Interdependence
Assign each member a role and rotate them

Resource Interdependence
1. Limit resources (one set of materials)
2. Jigsaw materials
3. Separate contributions

Task Interdependence
1. Factory-line
2. Chain Reaction

Outside Challenge Interdependence
1. Intergroup competition
2. Other class competition

Identity Interdependence
Mutual identity (name, motto, etc.)

Environmental Interdependence
1. Designated classroom space
2. Group has special meeting place

Fantasy Interdependence
Hypothetical interdependence in situation ("You are a scientific/literary prize team, lost on the moon, etc.")

Reward/Celebration Interdependence
1. Celebrate joint success
2. Bonus points (use with care)
3. Single group grade (when fair to all)

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http://www.ce.umn.edu/~smith
Skype: kasmithtc

Individual Accountability

Ways to ensure no slackers:
- Keep group size small (2-4)
- Assign roles
- Randomly ask one member of the group to explain the learning
- Have students do work before group meets
- Have students use their group learning to do an individual task afterward
- Everyone signs: "I participated, I agree, and I can explain"
- Observe & record individual contributions

Ways to ensure that all members learn:
- Practice tests
- Edit each other's work and sign agreement
- Randomly check one paper from each group
- Give individual tests
- Assign the role of **checker** who has each group member explain out loud
- Simultaneous explaining: each student explains their learning to a new partner

Face-to-Face Interaction

Structure:
- Time for groups to meet
- Group members close together
- Small group size of two or three
- Frequent oral rehearsal
- Strong positive interdependence
- Commitment to each other's learning
- Positive social skill use
- Celebrations for encouragement, effort, help, and success!

Key Elements:

- **Positive Interdependence**
- **Individual and Group Accountability**
- Face-to-Face Promotive Interaction
- Teamwork Skills
- Group Processing

Key elements of cooperative learning (CL) [CLHks.pdf]

Cooperative Learning Research Support

Johnson, D.W., Johnson, R.T., & Smith, K.A. 1998. Cooperative learning returns to college: What evidence is there that it works? *Change*, *30* (4), 26-35.*

Benefits

1. Achievement and retention
2. Critical thinking and higher-level reasoning
3. Differentiated views of others
4. Accurate understanding of others' perspectives
5. Liking for classmates and teacher
6. Liking for subject areas
7. Teamwork skills

- Over 300 Experimental Studies
- First study conducted in 1924
- High Generalizability
- Multiple Outcomes

Cooperative Learning - STEM - Meta Analysis

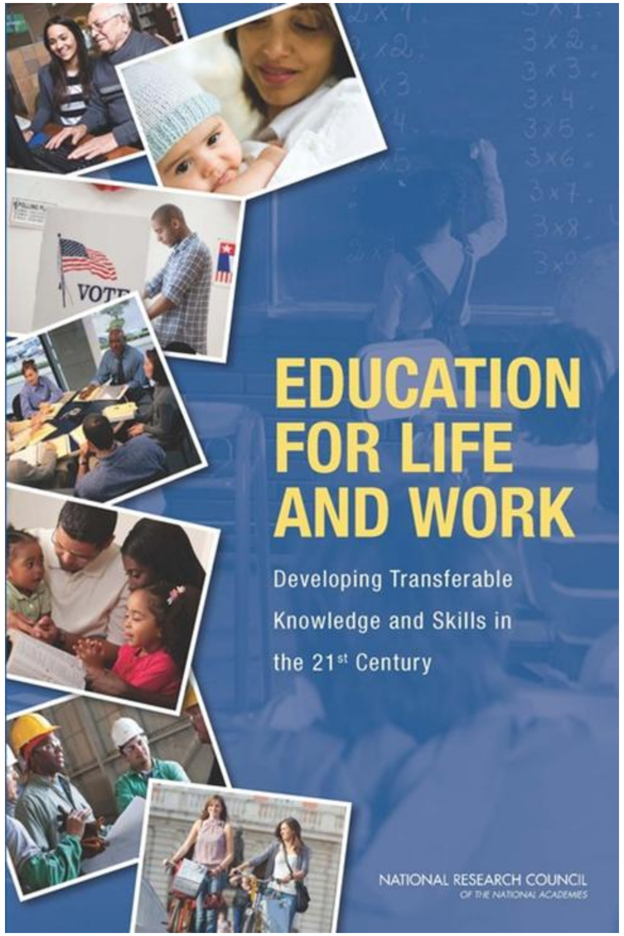
Springer, Stanne, and Donovan (1997, 1999) reported mean effect sizes for cooperative learnings effect on students' achievement and persistence of 0.51 and 0.46, respectively.

They observed that **"The 0.51 effect of small-group learning on achievement reported in this study would move a student from the 50th percentile to the 70th on a standardized test. Similarly, a 0.46 effect on students' persistence is enough to reduce attrition in STEM courses and programs by 22%."**

Springer, L., Stanne, M. E., and Donovan, S. 1997. Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Madison, WI: National Institute for Science Education.*

Springer, L., Stanne, M.E., and Donovan, S. S. 1999. Effect of Small Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis. *Review of Educational Research, 69*(1), 21–51.

Transferable Knowledge and Skills

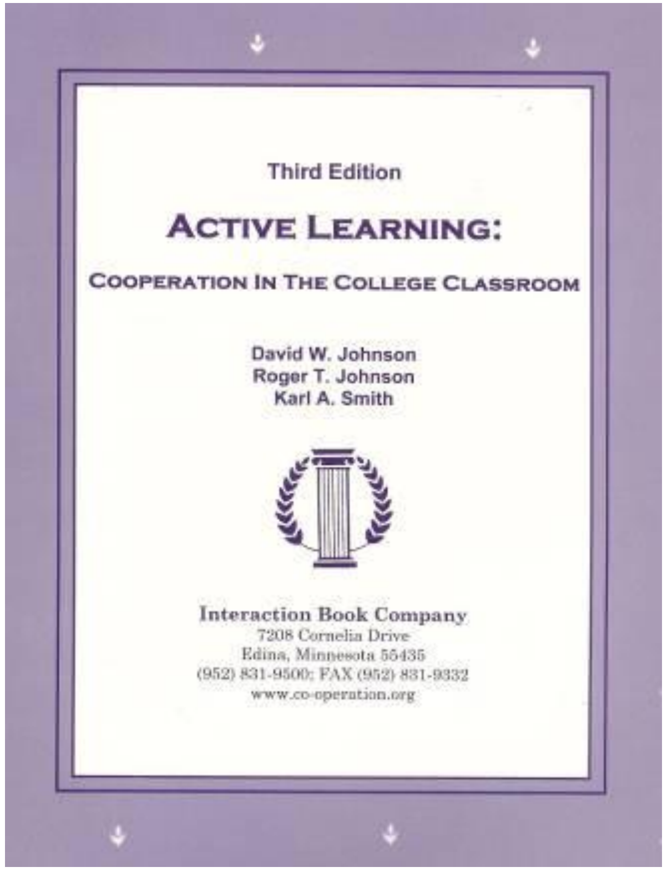


https://nap.nationalacademies.org/catalog/13398/education-for-life-and-work-developing-transferable-knowledge-and-skills

Cooperation in the College Classroom

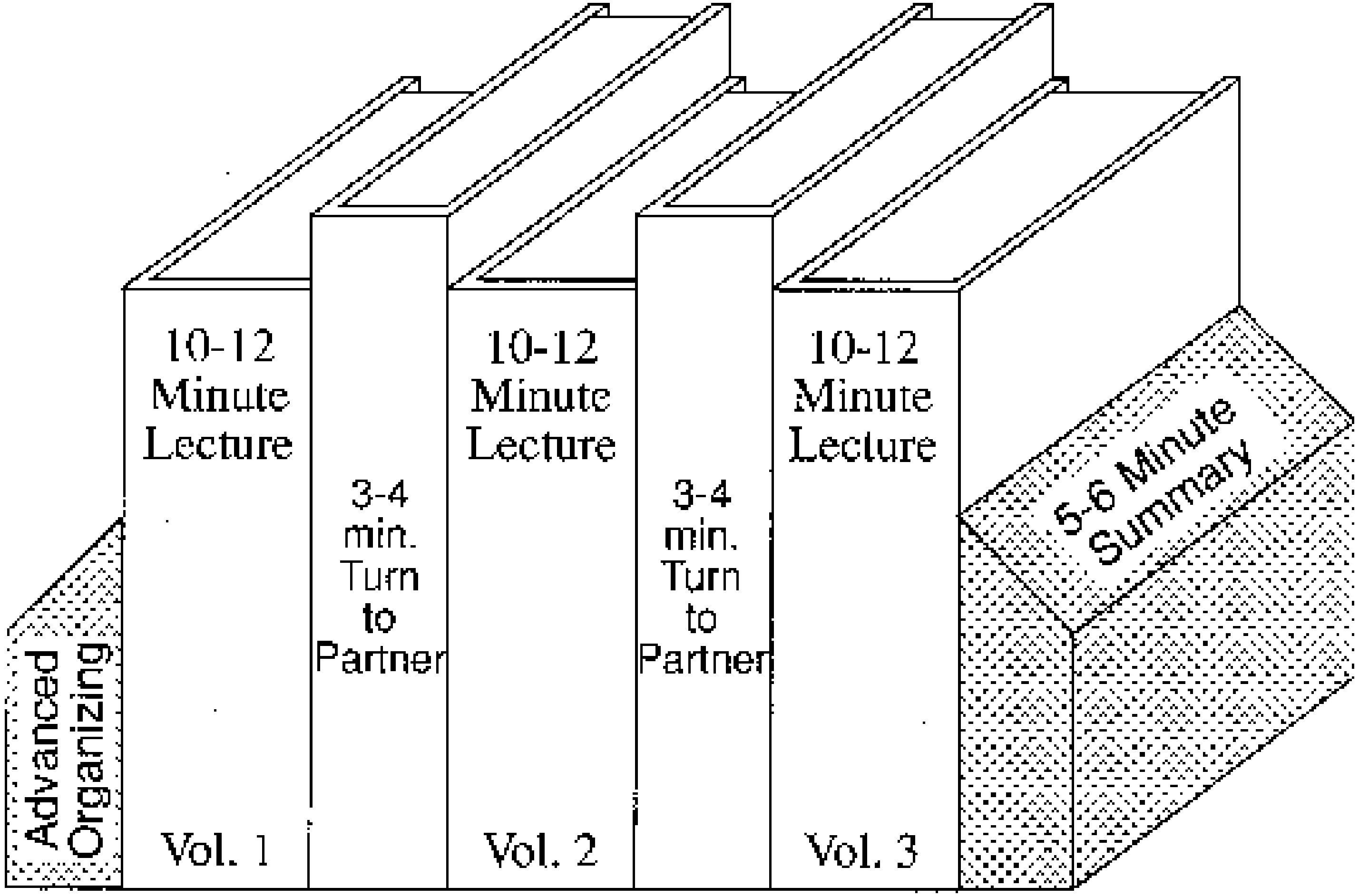
- ❑ **Informal** Cooperative Learning Groups
- ❑ **Formal** Cooperative Learning Groups
- ❑ Cooperative **Base** Groups

Notes: <u>Cooperative Learning Notes</u>



First edition 1991.

Book Ends on a Class Session



Smith, K.A. 2000. Going deeper: Formal small-group learning in large classes. Energizing large classes: From small groups to learning communities. *New Directions for Teaching and Learning*, 2000, 81, 25-46. [NDTL81Ch3GoingDeeper.pdf]

Book Ends on a Class Session

1. Advance Organizer

2. Formulate-Share-Listen-Create (Turn-to-partner) — *repeated every 10-12 minutes*

3. Session Summary (Minute Paper)
    1. What was the most useful or meaningful thing you learned during this session?
    2. What question(s) remain uppermost in your mind as we end this session?
    3. What was the "muddiest" point in this session?

1 Advance Organizer

"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly."

David Ausubel - Educational psychology: A cognitive approach, 1968.

2 Formulate-Share-Listen-Create

Informal Cooperative Learning Group
Introductory Pair Discussion of a

FOCUS QUESTION

1. Formulate your response to the question **individually**
2. Share your answer with a partner
3. Listen carefully to your partner's answer
4. Work together to Create a new answer through discussion

❷ Focus Question Examples

- Give an example
- Describe an application…
- Explain in your own words…
- Paraphrase the idea
- Support the following statement…

Informal Cooperative Learning Groups

- Can be used at any time
- Can be short term and ad hoc
- May be used to break up a long lecture
- **Provides an opportunity for students to process material they have been listening to (Cognitive Rehearsal)**
- Are especially effective in large lectures and one-time events (e.g., guest presentation)
- Include "book ends" procedure
- Are not as effective as Formal Cooperative Learning or Cooperative Base Groups

Cooperation in the College Classroom

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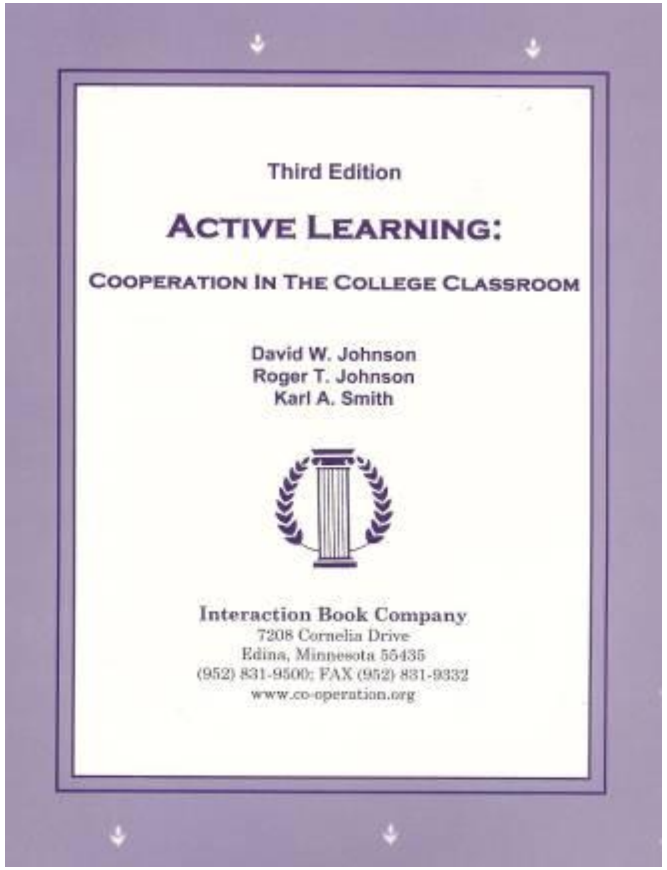
- ❑ **Formal** Cooperative Learning Groups
- ❑ Cooperative **Base** Groups

Notes: <u>Cooperative Learning Notes</u>



First edition 1991.

Instructor's Role in Formal Cooperative Learning

1. Specifying Objectives (Academic and Interpersonal/Teamwork)

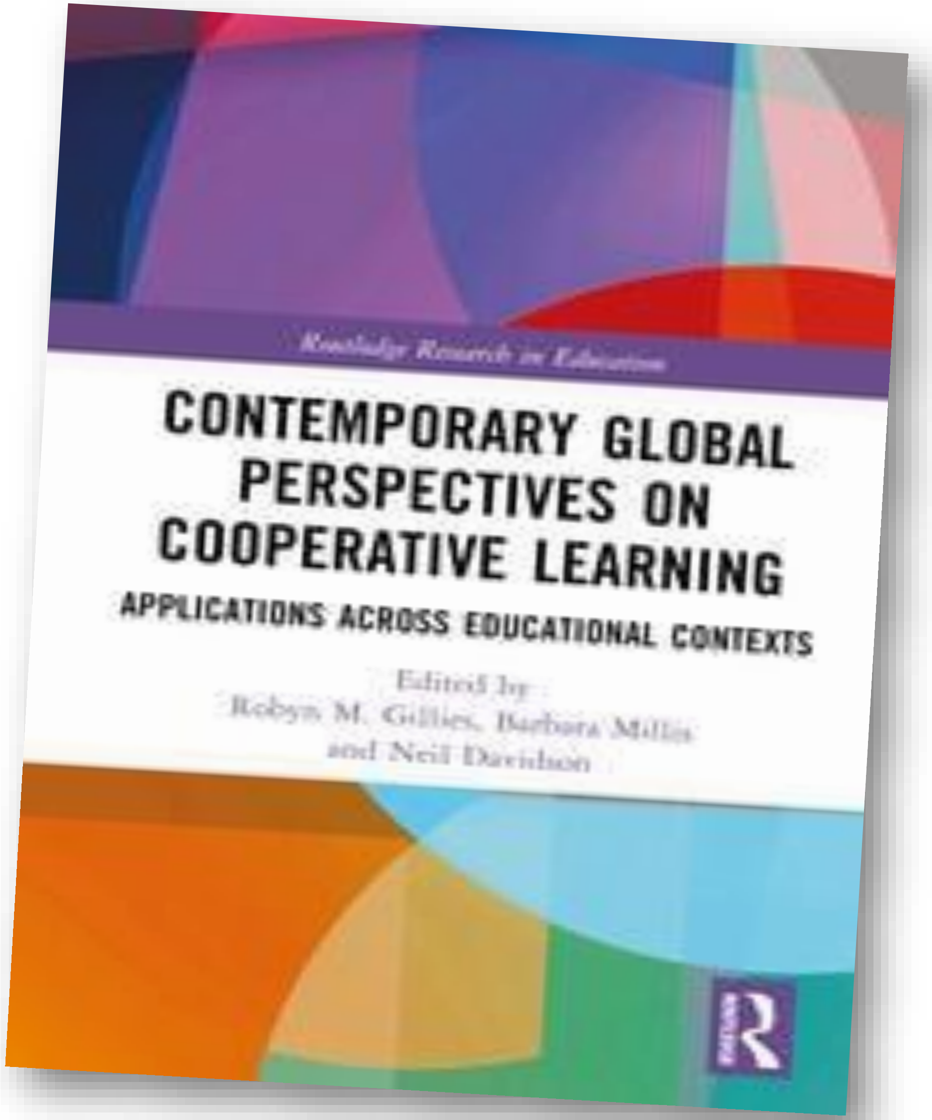
2. Making Decisions

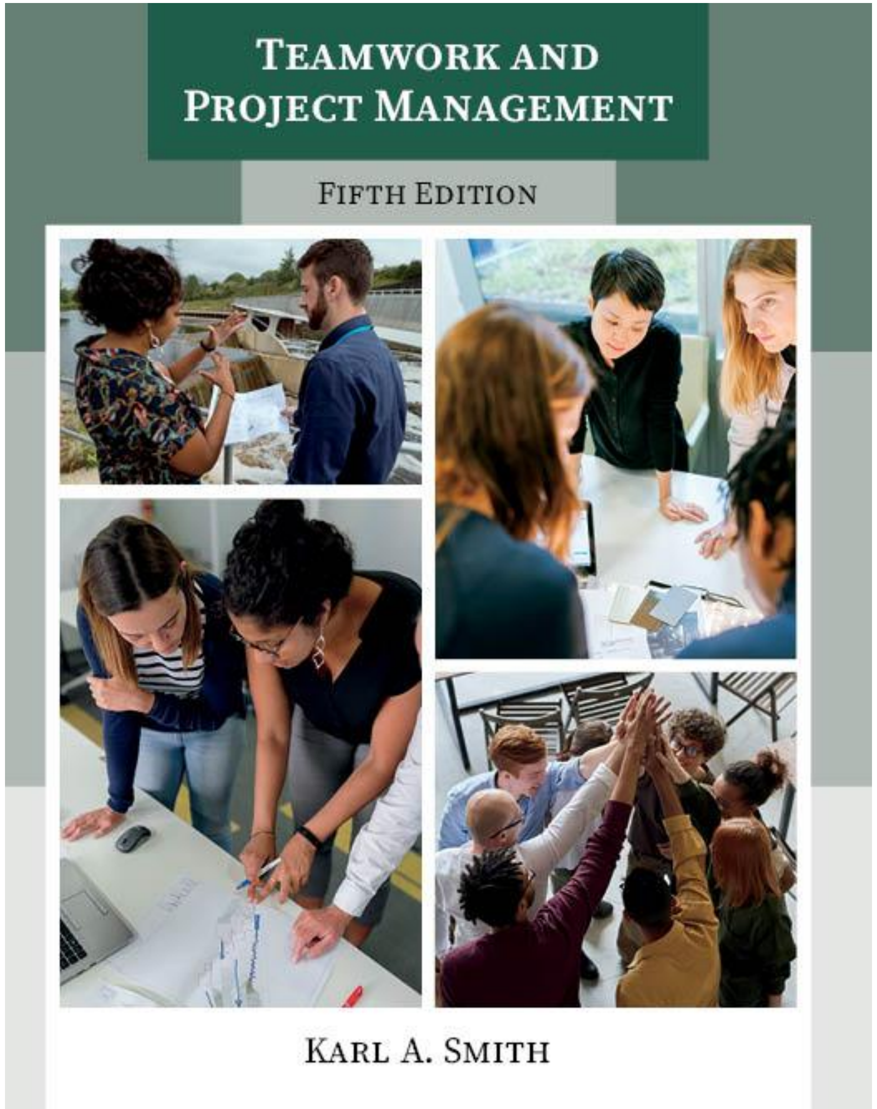
3. Explaining Task, Positive Interdependence, and Individual Accountability

4. Monitoring and Intervening to Teach Skills

5. Evaluating Students' Achievement and Group Effectiveness

Smith, K.A. & Felder, R.M. 2023. Cooperative Learning in Engineering Education: The Story of an Ongoing Uphill Climb. In Robyn Gillies, Barbara Millis, and Neil Davidson, eds. Contemporary Global Perspectives on Cooperative Learning Link to Draft





https://ladbookstore.com/products/teamwork-and-project-management-fifth-ed

Instructor and Facilitator Guide to Teamwork and Project Management

Russell Korte and Karl Smith

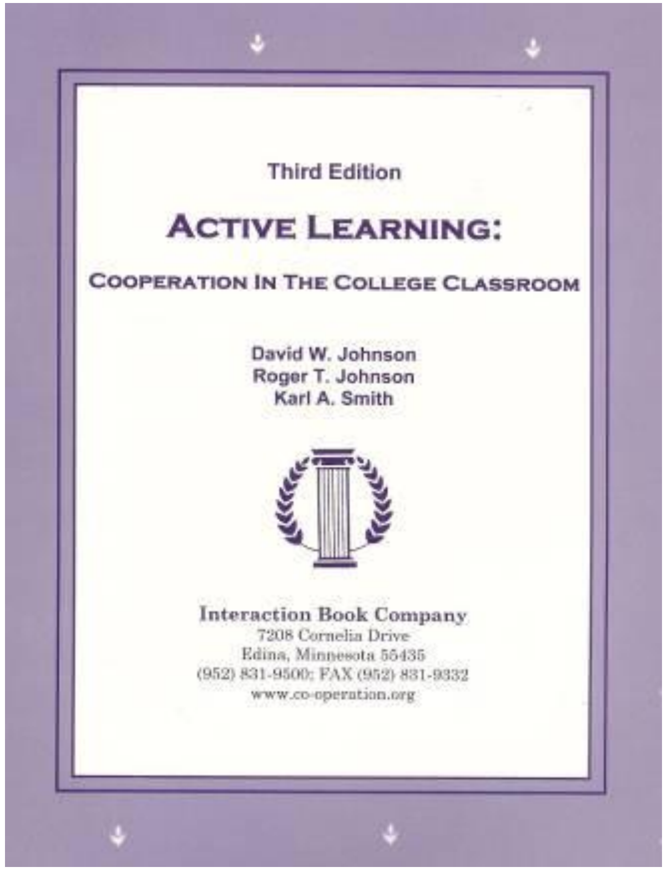
In Preparation

Get the book here:

Cooperation in the College Classroom

- **Informal** Cooperative Learning Groups
- **Formal** Cooperative Learning Groups
- Cooperative **Base** Groups

Notes: <u>Cooperative Learning Notes</u>



First edition 1991.

Cooperative Base Groups

Cooperative Base Groups are long-term, stable teams designed to support members’ academic and personal development beyond class activities.

People illustrations by Storyset

Major Shifts in Engineering Education (~1912-2012)

1. Engineering science - a shift from hands-on and practical emphasis to engineering science and analytical emphasis

2. Outcomes and accreditation - a shift to outcomes-based education and accreditation

3. Engineering design - a shift to emphasizing engineering design

4. Social-behavioral sciences - a shift to applying education, learning, and social-behavioral sciences research

5. ICC technologies - a shift to integrating information, computational, and communications technology in education

Froyd, J., Wankat, P. & Smith, K.A. (2012)   Smith, K.A. & Chavela, R. (2021)   Smith, K.A. (2024))

Shift 5 - Integration of Information, Communication, and Computational (ICC) Technologies

DELIVERY: Television, Audio & Video Tape & Internet

Individualized Feedback

Personal Response Systems (clickers)

Intelligent Tutors

Computational Technologies

Grading

Simulations

Games and Competitions

IMPLICATIONS:

Technology provides affordances to mediate learning—but education is a human activity.

AI

Term "AI" coined in 1956 by John McCarthy

↓

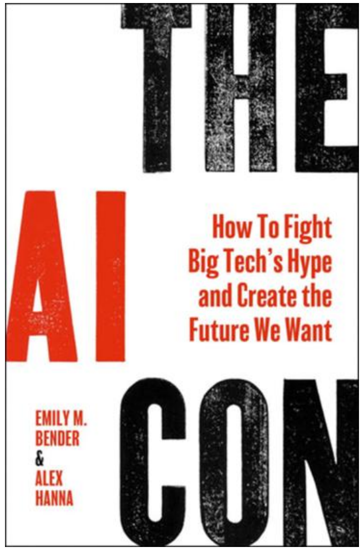
Generative AI

ChatGPT (November 2022)

IMPLICATIONS:

AI is increasingly impacting engineering education:

- Coding
- Writing
- ?



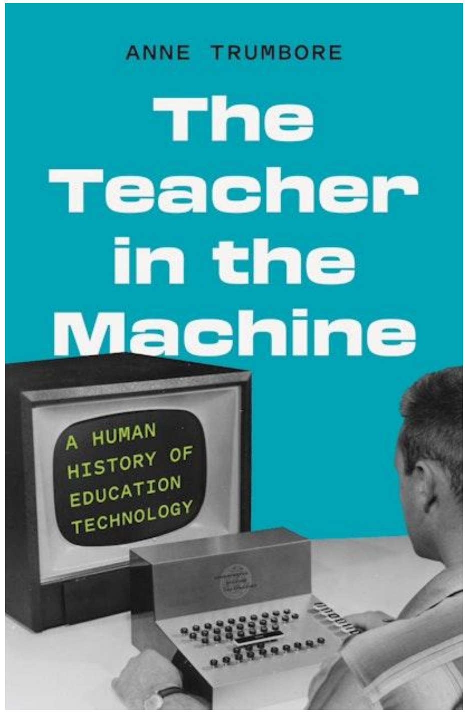
Pablo M. Tagarro. Forget the future, AI is causing harm now. *Science* **388**,595-595(2025). DOI:10.1126/science.adw3900

Technology and Teachers

- Film (Edison)
- Radio
- TV
- Computer
  - PLATO (Programmed Logic for Automatic Teaching Operations) (1960)
  - “Goodbye, Teacher” Keller (1968)
  - "Any teacher who can be replaced by a CD should be" (Jack Wilson)
- AI

“Technology always seems poised to revolutionize education — until it doesn’t” Jonathan Wai

Jonathan Wai, The next best way to teach and learn. *Science* **388**, 920-920(2025). DOI:10.1126/science.adx4571



“Why are we so eager to turn to technology to solve educational problems for which **the one reliably proven solution is more person-to-person connection**?”

Prior Shifts

- Engineering science
- Outcomes and accreditation
- Engineering design
- Social-behavioral sciences
- ICC technologies

Pandemic Shifts

- Ubiquitous remote Teaching & Learning
- Justice, equity, diversity, and inclusion (JEDI)

The Time of Coronavirus

Ubiquitous Remote Teaching and Learning

Emergency Remote Teaching

↓

Effective Distance Education

IMPLICATIONS:

Engineering teaching and learning can be accomplished remotely—but there are challenges:

- Video conference fatigue
- Lack of human/social interaction

Poll: What is your approach to teaching and learning during the pandemic?

Remote synchronous (live/real time)	(24) 53%
Asynchronous/self-paced	(2) 4%
Hybrid/blended	(18) 40%
In person	(1) 2%

Poll: How is remote teaching/learning going (compared to pre-pandemic)?

Much better than before (5/47) 11%

Better than before (16/47) 34%

About the same as before (13/47) 28%

Worse than before (13/47) 28%

Much worse than before (3/47) 6%

Emphasis on Justice, Equity, Diversity, and Inclusion

Be Identity-conscious

Be Relational

Be Transparent

Be Accessible

Be Proactive

Be Flexible

Do the best you can until you know better. Then when you know better, do better.”

—Maya Angelou

IMPLICATION:

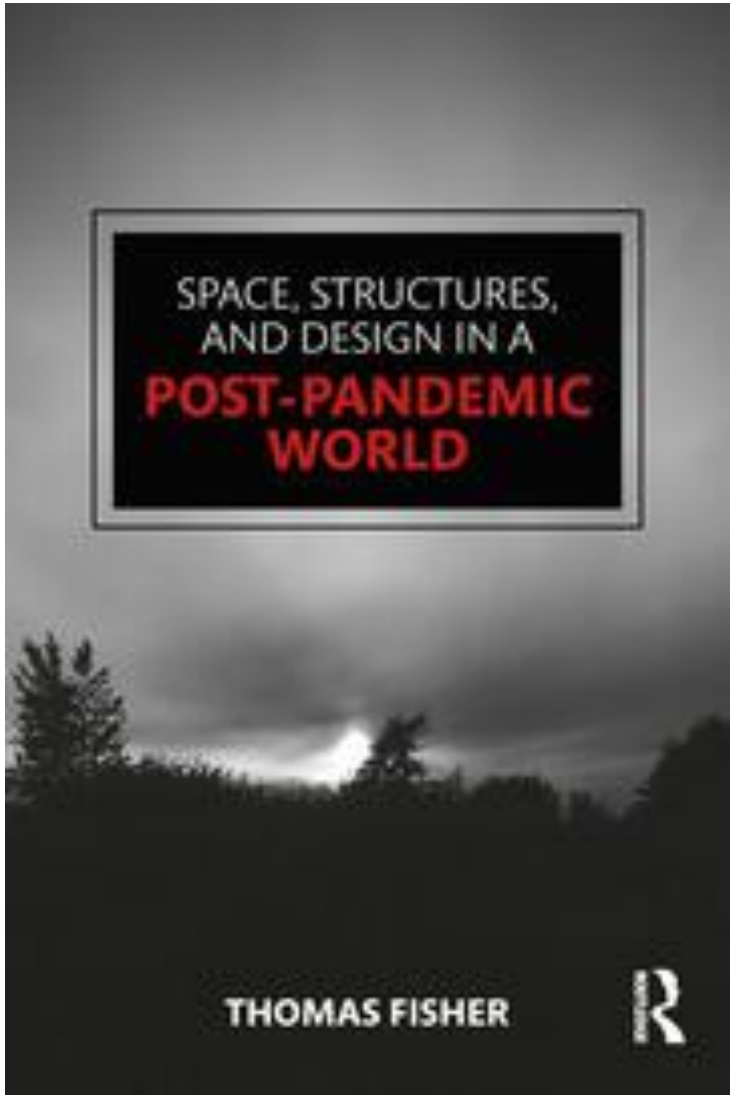
Working towards creating and maintaining equitable and inclusive learning environments is imperative.

End racism in science: there shouldn’t be any argument about this goal. *Nature* **641**, 1071 (2025) *doi: https://doi.org/10.1038/d41586-025-01615-w*

https://www.celt.iastate.edu/wp-content/uploads/2020/06/Equity-and-Inclusion-in-the-Online-Learning-Environment.pdf

Pandemics

1. Accelerate us into the future and magnify trends
2. Reveal inequities and dysfunctions in existing systems
3. Bring renewed attention to public & personal health
4. Create opportunities for those who grasp the change



The impact on education

Cholera, 1852-4

- Land-Grant Universities
- Morrill Act 1857-1862

Flu, 1918-20

- Junior Colleges
- AAJC, 1920

COVID, 2020-22

- Alternative Universities?

HOW TRUMP UPENDED SCIENCE

A chaotic 100-day push to remake federal research will have lasting consequences

DAVID MALAKOFF

It is almost certainly the most consequential 100 days that scientists in the United States have experienced since the end of World War II.

Since taking his oath of office on 20 January, President Donald Trump has unleashed an unprecedented rapid-fire campaign to remake—some would say demolish—vast swaths of the federal government's scientific and public health infrastructure. His administration has erased entire agencies that fund research; fired or pushed out thousands of federal workers with technical backgrounds; terminated research and training grants and contracts worth billions of dollars; and banned new government funding for activities it finds offensive, from efforts to diversify the scientific workforce to studies of the health needs of LGBTQ people. The frenetic onslaught has touched nearly every field—from archaeology to zoology, from deep-sea research to deep-space science. And it has left researchers from postdocs to lab heads feeling bewildered, worried—and angry. Many fear that in just 14 weeks, Trump has irreversibly damaged a scientific enterprise that took many decades to build, and has long made the U.S. the envy of the world.

It is too soon to know whether those fears will prove prescient. But now that Trump has marked the 100th day of his second term, *Science* is putting a spotlight on just a few of the many ways his administration is reshaping U.S. science. Numbers tell part of the story (see graphics, p. 577), highlighting how the administration has slowed the flow of research spending at key agencies and threatened to deny vast sums to universities. At the National Institutes of Health, the world's largest funder of biomedical research, the body blows have left researchers uncertain and anxious about what's to come (see p. 578). A more personal perspective comes from a handful of researchers who agreed to share their experience of the first 100 days, which for some meant losing a job or hopes of a future career (see p. 581).

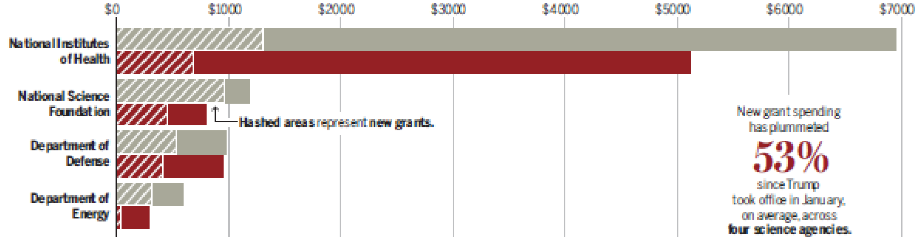
Although it can be hard to believe so much has already happened so quickly, many in the research community are now focusing on what might happen in the remaining 1361 days of Trump's term. Federal judges, for example, will be issuing rulings in numerous lawsuits that have implications for research, and the White House has released spending plans that could have major implications for science for years to come (see pp. 566 and 584). For better or worse, the story has just begun, and the end is nowhere in sight.

PHOTO: CHIP SOMODEVILLA/GETTY IMAGES

Science spending plummets

Since Donald Trump was inaugurated as president on 20 January, the largest federal agency funders of research have spent billions less on grants, compared with the same 3-month period in 2024. Causes include a freeze on federal spending and administration reviews to root out and terminate grants on topics banned by Trump's executive orders on diversity and "gender ideology."

Grant amounts (millions of dollars) provided between 20 January–15 April*: 2024 2025

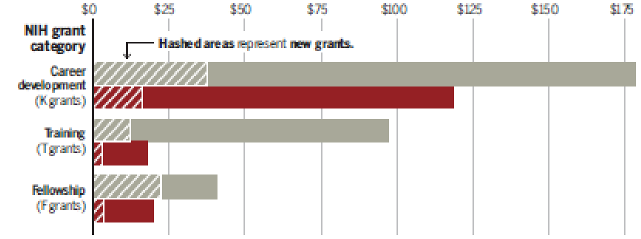


*National Institutes of Health data are updated more frequently and include grants through 19 April.

Workforce funding slashed

A slowdown by the National Institutes of Health (NIH) and National Science Foundation (NSF) in grantmaking for training students and early-career scientists threatens to narrow the research workforce pipeline. The squeeze has affected several grant types designed specifically for that purpose. Some of the reductions likely resulted from directives from the Trump administration ending federal support for programs involving diversity, equity, and inclusion. (Grant money for training also comes from other sources, such as research grants, not shown here.)

Grant amounts (millions of dollars) provided between 20 January–18 April: 2024 2025



NSF fellowships halved

2037 new awards for **graduate research fellowships** were given by NSF in 2024.

1000 new fellowships have been awarded so far by NSF for 2025, which may be the final total for the year.

Big research universities take a hit

The Trump administration says it has frozen or terminated research grants at several elite institutions, citing concerns such as that they violated federal civil rights law by inadequately responding to alleged antisemitism on their campuses. Amounts shown reflect multiyear awards.

At least $5 billion has been frozen at eight universities because of alleged civil rights violations.

Six of these institutions are among **60 UNIVERSITIES** under investigation by the Trump administration for alleged antisemitic discrimination.

An additional **$17 BILLION** of their federal research funds is at risk. Also at risk is research funding for **40 other academic institutions** the administration is investigating for alleged racial discrimination.

*University of Maine frozen funds were restored after Senator Susan Collins (R–ME) interceded. Cornell University reported its cuts would amount to more than $1 billion. All other figures are based on announcements from the Trump administration; in most cases, universities have not verified frozen or canceled funding. The estimate of $17 billion is based on data reported by institutions in FY2023.

See **https://scim.ag/Trump100data** for data methodology used in all charts.

https://www.science.org/content/article/100-days-that-shook-u-s-science

Defunding Research

NSF Created in 1950

↓

57% budget reduction and termination of many grants

IMPLICATIONS:

Engineering education and DBER research affected:

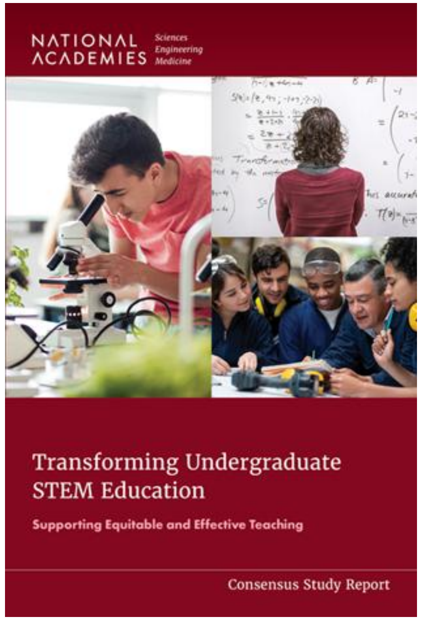
- DEI
- ?
- ?

Prior Shifts

- Were prompted by outside forces
- Were met with resistance
- Were eventually embraced (to varying degrees)
- **Did not change core values/practices**

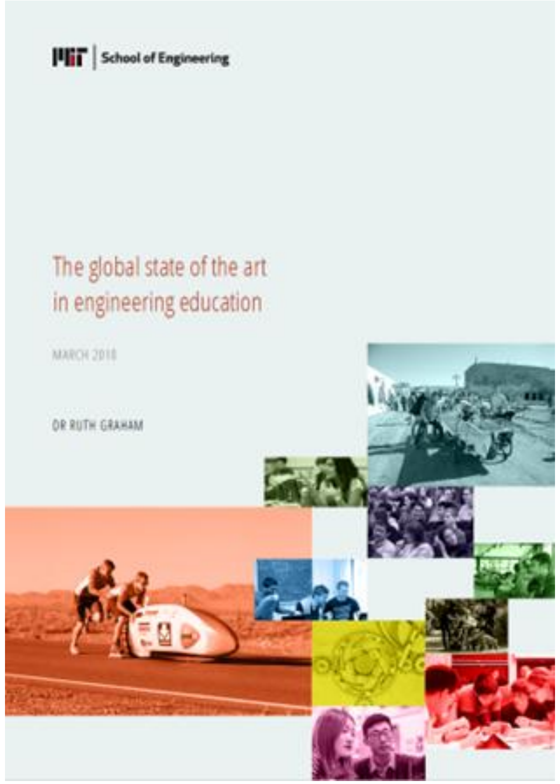
Post-Pandemic

Are core values/practices in jeopardy?



Decades of research show that learning involves a set of complex processes and is shaped by the characteristics and experiences of learners, social interactions, and cultural context. **Studies are clear that student-centered instructional practices** that take students' interests and experiences into account and provide them with authentic opportunities to engage with disciplinary content, practices, and analysis **are more effective** than instructional practices that rely primarily on lecture, reading, and memorization of content, procedures, and algorithms.

https://nap.nationalacademies.org/catalog/28268/transforming-undergraduate-stem-education-supporting-equitable-and-effective-teaching



This is the future of the field, where you **put the student at the center and use the resources to facilitate team projects and authentic experiences**, and then put the taught curriculum online.

https://www.rhgraham.org/resources/Global-state-of-the-art-in-engineering-education---March-2018.pdf

Reflection and Dialogue

Individually reflect on the recent shifts to engineering education:

- **Prior shifts 4. Social - Behavioral Science and 5. ICC Technologies**
- **Two pandemic shifts (Remote Teaching and JEDI)**
- **The current shift of Defunding Science**

Think/write individually for about 1 minute.

Discuss with your neighbor for about 2 minutes

Select/create a response – question or comment – to present to the whole group if you are randomly selected

Questions & Discussion

Thank you!

An eCopy of this presentation will be posted to karlsmithmn.org

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