Design and Implementation of Cooperative Learning in Introductory Physics

Karl A. Smith
Civil, Environmental & Geo- Engineering—University of Minnesota & Engineering Education – Purdue University
ksmith@umn.edu
https://karlsmithmn.org/
University of Minnesota Collaborative Model for Large Introductory Courses

STUDENTS

LECTURE
- TOPICS
- DEMOS
- EXAMS
- QUIZES
- HOMEWORK

OFFICE HOURS

DISCUSSION

LABS
- PROBLEM SOLVING
- CONTEXT RICH PROBLEMS

COOPERATIVE GROUPS

GRADING

TEAM

LECTURERS

LECTURER

TAs

MENTOR TAc

ALL TA MEETINGS

ORIENTATION

University of MN, Physics Education Research and Development, 1996
Problem Solving *a la* Martinez

“Process of Moving Toward a Goal When Path is Uncertain.”

- If you know how to do it, it’s not a problem.
  
  *(Exercise vs Problem)*

“Problem Solving Involves **Error and Uncertainty**”

A problem for your students is not a problem for you.

M. Martinez, *Phi Delta Kappan*, April, 1998
It is strange that we expect students to learn, yet seldom teach them anything about learning. We expect students to solve problems, yet seldom teaching them anything about problem solving. And, similarly, we sometimes require students to remember A considerable body of material, yet seldom teach them the art of memory. **It is time we made up for this lack...**

Learning: Emphasize Big Ideas (Enduring Outcomes)*

- How People Learn
- Streamlined Course Design
  - Alignment of Outcomes, Assessment and Instruction
- Interactive Learning

*See Streveler and Smith (2021), Course design in the time of coronavirus: Put on your designer’s CAP. Advances in Engineering Education.

https://advances.asee.org/opinion-course-design-in-the-time-of-coronavirus-put-on-your-designers-cap/
Learning Requires*

deliberate
distributed
practice

*Thanks to Ruth Streveler for these slides
Key Implications

Deliberate

Attention must be paid

Attention and processing power = cognitive load (bandwidth)
  • LIMITED – need to be careful how one uses the learner’s bandwidth
    • Link to Curricular Priorities
    • Continuous partial attention

• Reflection is needed
  • Need for feedback
    • Link to assessment
Key Implications

 Distributed

 Repetition over time
  ◦ Spaced vs. massed practice*
  ◦ Spiral curriculum**

 Multiple modes of input
  ◦ Visual
  ◦ Audio
  ◦ Kinesthetic
  ◦ Self-explanation
  ◦ Explaining to others


**a concept widely attributed to Jerome Bruner, refers to a curriculum design in which key concepts are presented repeatedly throughout the curriculum, but with deepening layers of complexity, or in different applications.
Key Implications

Practice what you want to learn

Attentive – doing something

Constructive – adding to your prior knowledge

Interactive – working with others to add to your prior knowledge

## I-C-A-P Framework

<table>
<thead>
<tr>
<th>ACTIVE–ATTENTIVE</th>
<th>CONSTRUCTIVE</th>
<th>INTERACTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing something physically</td>
<td>Producing outputs that go beyond presented information</td>
<td>Dialoguing substantively on the same topic, and not ignoring a partner’s contribution</td>
</tr>
<tr>
<td>Paying Attention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engaging activities</td>
<td>Self-construction</td>
<td>Guided-construction</td>
</tr>
<tr>
<td>Attending processes</td>
<td>Creation processes</td>
<td>Joint creation processes</td>
</tr>
</tbody>
</table>

Interactive > Constructive > Attentive > Passive

ICAP framework, Michelene T.H. Chi

Cognitive apprenticeship (1 of 3)

1. Authentic tasks/situations
2. Narrated modeling
   ◦ Challenges of this approach
     ◦ Expert not used to explaining thinking
     ◦ Expert forgets what is it like to be learning the material, “expert blind spot”
     ◦ Subconscious or intuitive knowledge - “mystery of expert judgment”
3. Scaffolded and coached practice
   ◦ **Scaffold** from learner’s prior knowledge to new info
   ◦ **Coach** can diagnose “problems” and correct
   ◦ Immediate feedback – important for motivation
   ◦ Informational feedback
Cognitive apprenticeship (3 of 3)

3. **Articulation of the steps by the learner**
   - Self-explanation

4. **Reflection on the process by the learner**
   - Consolidates the skill, improves retention


Session Layout

Welcome & Overview

Cooperative Learning
  ◦ Description & Rationale
  ◦ Cooperative Learning
    ◦ Key Concepts
    ◦ Types of Cooperative Learning

Teamwork – High Performing Teams & Teamwork Skills

Implementing Cooperative Learning
  ◦ Practice
  ◦ Examples
  ◦ Applications
Overall Goals

- Build your knowledge of Cooperative Learning and your implementation repertoire
- Implement practices to improve student learning, especially their problem solving skills
Cooperative Learning Objectives

Participants will be able to list and describe essential features of the instructor’s role in implementing cooperative learning

Participants will be able to elaborate on multiple ways Positive Interdependence and Individual Accountability were structured

Participants will identify features to implement in their own courses
Reflection and Dialogue

Individually reflect on your experience as an undergraduate student with Interactive (cooperative) learning. Write for about 1 minute.

◦ First time you heard the term in a class setting or the first time you were asked to work with others in a class setting
◦ What did the instructor ask you to do?
◦ What rationale did the instructor provide?

Discuss with your neighbor for about 2 minutes
◦ Select/create a response to present to the whole group if you are randomly selected
Karl’s Experience

First Teaching Experience – Third-year course in metallurgical reactions – thermodynamics and kinetics
Process Metallurgy

Dissolution Kinetics – liquid-solid interface
Iron Ore Desliming – solid-solid interface
Metal-oxide reduction roasting – gas-solid interface
Dissolution Kinetics

Theory – Governing Equation for Mass Transport

Research – rotating disk

Practice – leaching of silver bearing metallic copper and printed circuit board waste

\[ (\nabla c \cdot \nabla y) = D \nabla^2 c \]

\[ v_y \frac{dc}{dy} = D \frac{d^2 c}{dy^2} \]
Karl’s Quandry

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

Theory – ?

Research – ?
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
- Social psychology of learning – student – student interaction
Cooperative Learning


Research Evidence – Randomized Design Field Experiments

Practice – Formal Teams/Professor’s Role

Diagram: Theory, Research Evidence, Practice
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).
Key Concepts:

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

Cooperative Learning Introduced to Engineering – 1981


Undergraduate Teaching Faculty: The 2013–2014 HERI Faculty Survey

Figure 2. Changes in Faculty Teaching Practices, 1989 to 2014 (% Marking “All” or “Most” Courses)

<table>
<thead>
<tr>
<th>Methods Used in “All” or “Most”</th>
<th>STEM women</th>
<th>STEM men</th>
<th>All other women</th>
<th>All other men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative learning</td>
<td>60%</td>
<td>41%</td>
<td>72%</td>
<td>53%</td>
</tr>
<tr>
<td>Group projects</td>
<td>36%</td>
<td>27%</td>
<td>38%</td>
<td>29%</td>
</tr>
<tr>
<td>Grading on a curve</td>
<td>17%</td>
<td>31%</td>
<td>10%</td>
<td>16%</td>
</tr>
<tr>
<td>Student inquiry</td>
<td>43%</td>
<td>33%</td>
<td>54%</td>
<td>47%</td>
</tr>
<tr>
<td>Extensive lecturing</td>
<td>50%</td>
<td>70%</td>
<td>29%</td>
<td>44%</td>
</tr>
</tbody>
</table>

Effectiveness of Interactive Learning

- Meta-analyses in the *Proceedings of the National Academy of Sciences (PNAS)* summarize the importance of interactive learning for
  - reducing the failure rate (Freeman, et.al. 2014) [https://www.pnas.org/content/111/23/8410](https://www.pnas.org/content/111/23/8410)
  - narrowing the achievement gap for underrepresented students (Theobald, et.al. 2019) [https://www.pnas.org/content/117/12/6476](https://www.pnas.org/content/117/12/6476)
Observational study of over 2000 classes – most common behaviors:

- **Faculty**
  - Lecturing
  - Writing in real time
  - Posing nonrhetorical questions
  - Following-up on questions
  - Answering student questions
  - Clicker questions

- **Students**
  - Listening to instructor
  - Answering instructor questions
  - Asking questions

http://science.sciencemag.org/content/sci/359/6383/1468.full.pdf
Structuring Teamwork in the Classroom

Formal Cooperative Learning Task Groups
Teamwork

- Pseudo-group
- Traditional Group
- Cooperative Group
- High-performing Cooperative Group
- Individual Members

PERFORMANCE LEVEL

TYPE OF GROUP

- Teamwork
Reflection and Dialogue

Individually reflect on the Characteristics of High Performing Teams. Think/Write for about 1 minute

◦ Base on your experience on high performing teams,
◦ Or your facilitation of high performing teams in your classes,
◦ Or your imagination

Discuss with your team for about 2 minutes and record a list
Characteristics of High Performing Teams

☐ ?
Characteristics of High Performing Teams – Physics TAs - 2019

- Respect for one another
- Good leadership
- Diversity of ideas and diversity of skills
- Common work ethic
- Health conflict
- Sense of comraderies, actual cooperative group, good participation
- Common goal
- Motivation
- Systematic organization
- No ego
- External check
- To agree/not be afraid of being wrong
Characteristics of High Performing Teams – Physics TAs - 2018

- Diversity of experience
- People had one another’s backs
- Feel safe presenting ideas – cooperative not competitive
- Group members pushing one another to do well
- Holding one another accountable
- Respecting one another’s idea
- Levity – sense of humor
- People aren’t afraid to ask question
- Help shy people to talk, e.g., ask shy folks what they think
- Responsibility and flexibility – responsible for own work. Flexible in tacking issues
- Come to a conclusion as a group – make sure everyone understands
- Similar motivations
A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable:

- SMALL NUMBER
- COMPLEMENTARY SKILLS
- COMMON PURPOSE & PERFORMANCE GOALS
- COMMON APPROACH
- MUTUAL ACCOUNTABILITY

--Katzenbach & Smith (1993)

_The Wisdom of Teams_
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).

Key Concepts

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

Six Basic Principles of Team Discipline

Keep membership small
Ensure that members have complimentary skills
Develop a common purpose
Set common goals
Establish a commonly agreed upon working approach
Integrate mutual and individual accountability

Katzenbach & Smith (2001) The Discipline of Teams
Cooperation in the College Classroom

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

Notes: [Cooperative Learning Notes](#)
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
Cooperative Problem-Based Learning Format

**TASK:** Solve the problem(s) or Complete the project.

**INDIVIDUAL:** Develop ideas, Initial Model, Estimate, etc. Note strategy.

**COOPERATIVE:** One set of answers from the group, strive for agreement, make sure everyone is able to explain the strategies used to solve each problem.

**EXPECTED CRITERIA FOR SUCCESS:** Everyone must be able to explain the model and strategies used to solve each problem.

**EVALUATION:** Best answer within available resources or constraints.

**INDIVIDUAL ACCOUNTABILITY:** One member from your group may be randomly chosen to explain (a) the answer and (b) how to solve each problem.

**EXPECTED BEHAVIORS:** Active participating, checking, encouraging, and elaborating by all members.

**INTERGROUP COOPERATION:** Whenever it is helpful, check procedures, answers, and strategies with another group.

- Thinking Like an Engineer
- Problem Identification
- Problem Formulation
- Problem Representation
- Problem Solving
Team Member Roles

- Task Recorder
- Skeptic/Prober
- Process Recorder/facilitator
Technical Estimation Problem

**TASK:**

**INDIVIDUAL:** Quick Estimate (10 seconds). Note strategy.

**COOPERATIVE:** Improved Estimate (~5 minutes). One set of answers from the group, strive for agreement, make sure everyone is able to explain the strategies used to arrive at the improved estimate.

**EXPECTED CRITERIA FOR SUCCESS:** Everyone must be able to explain the strategies used to arrive at your improved estimate.

**EVALUATION:** Best answer within available resources or constraints.

**INDIVIDUAL ACCOUNTABILITY:** One member from your group may be randomly chosen to explain (a) your estimate and (b) how you arrived at it.

**EXPECTED BEHAVIORS:** Active participating, checking, encouraging, and elaborating by all members.

**INTERGROUP COOPERATION:** Whenever it is helpful, check procedures, answers, and strategies with another group.
Group Reports

Estimate
  ◦ Group 1
  ◦ Group 2
  ◦ ...

Strategy used to arrive at estimate – assumptions, model, method, etc.
<table>
<thead>
<tr>
<th>Number of Ping Pong Balls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr 1 –</td>
</tr>
<tr>
<td>Gr 2 –</td>
</tr>
<tr>
<td>Gr 3 –</td>
</tr>
<tr>
<td>Gr 4 –</td>
</tr>
<tr>
<td>Gr 5 –</td>
</tr>
<tr>
<td>Gr 6 –</td>
</tr>
<tr>
<td>Gr 7 –</td>
</tr>
<tr>
<td>Gr 8 –</td>
</tr>
<tr>
<td>Gr 9 –</td>
</tr>
</tbody>
</table>
Model 1 (lower bound)

let \( L \) be the length of the room,
let \( W \) be its width,
let \( H \) be its height,
and let \( D \) be the diameter of a ping pong ball.

Then the volume of the room is
\[
V_{\text{room}} = L \times W \times H,
\]

and the volume of a ball (treating it as a cube) is
\[
V_{\text{ball}} = D^3,
\]

so number of balls = \( \frac{V_{\text{room}}}{V_{\text{ball}}} = \frac{L \times W \times H}{D^3} \).
Model 2 (upper bound)

let $L$ be the length of the room,
let $W$ be its width,
let $H$ be its height,
and let $D$ be the diameter of a ping pong ball.

Then the volume of the room is

$$V_{\text{room}} = L \times W \times H,$$

and the volume of a ball (treating it as a sphere) is

$$V_{\text{ball}} = \frac{4}{3} \pi r^3,$$

so number of balls $= \frac{V_{\text{room}}}{V_{\text{ball}}} = \frac{L \times W \times H}{\frac{4}{3} \pi r^3}$. 
Model 1 \( (V_{\text{room}} / D_{\text{ball}}^3) = \) Lower Bound

Model 2 \( (V_{\text{room}} / (4/3 \pi r_{\text{ball}}^3)) = \) Upper Bound

Upper Bound/Lower Bound = \( 6/\pi \approx 2 \)

How does this ratio compare with
1. The estimation of the diameter of the ball?
2. The estimation of the dimensions of the room?
Real World

Model World

Model

$V_r/V_b$

Calc
Modeling

Modeling in its broadest sense is the cost-effective use of something in place of something else for some cognitive purpose (Rothenberg, 1989). A model represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality.

Any model is characterized by three essential attributes: (1) Reference: It is of something (its "referent"); (2) Purpose: It has an intended cognitive purpose with respect to its referent; (3) Cost-effectiveness: It is more cost-effective to use the model for this purpose than to use the referent itself.

Modeling Heuristics

1. Do not build a complicated model when a simple one will suffice.
2. Beware of molding the problem to fit the technique.
3. The deduction phase of modeling must be conducted rigorously.
4. Models should be validated prior to implementation.
5. A model should never be taken too literally.
6. A model should neither be pressed to do, nor criticized for failing to do, that for which it was never intended.
7. Beware of overselling a model.
8. Some of the primary benefits of modeling are associated with the process of developing the model.
9. A model cannot be any better than the information that goes into it.
10. Models cannot replace decision makers.
Group Processing
Plus/Delta Format

<table>
<thead>
<tr>
<th>Plus (+)</th>
<th>Delta (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Things That Group Did Well</td>
<td>Things Group Could Improve</td>
</tr>
</tbody>
</table>
*Based on First Year Engineering course – Problem-based cooperative learning How to Model It published in 1990.
Problem-Based Learning

- Problem posed
- Learn it
- Identify what we need to know
- Apply it

Subject-Based Learning

- Told what we need to know
- Learn it
- Given problem to illustrate how to use it

Normative Professional Curriculum:

1. Teach the relevant basic science,
2. Teach the relevant applied science, and
3. Allow for a practicum to connect the science to actual practice.
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).

Key Concepts

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Instructor’s Role in Formal Cooperative Learning

1. Specifying **Objectives** (Academic and Social/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
Decisions, Decisions...

- Group size?
- Group selection?
- Group member roles?
- How long to leave groups together?
- Arranging the room?
- Providing materials?
- Time allocation?
Optimal Group Size?

A. 2
B. 3
C. 4
D. 5
E. 6
Formal Cooperative Learning Task Groups

Group Selection?

A. Self selection
B. Random selection
C. Stratified random
D. Instructor assign
E. Other
Assigning Roles

Chapter 8: Group Roles and Responsibilities

- Roles
  - Facilitator
  - Checker
  - Set-Up
  - Materials Manager
  - Safety Officer
  - Reporter
- Dividing the labor
Teamwork Skills

- Communication
  - Listening and Persuading
- Decision Making
- Conflict Management
- Leadership
- Trust and Loyalty

Cooperative Teamwork Skills

- Forming Skills
  - Initial Management Skills
  - Move Into Groups Quietly
  - Stay With the Group
  - Use Quiet Voices
  - Take Turns
  - Use Names, Look at Speaker
  - No “Put-Downs”

- Functioning Skills
  - Group Management Skills
  - Share Ideas and Opinions
  - Ask for Facts and Reasoning
  - Give Direction to the Group’s Work (state assignment purpose, provide time limits, other procedures)
  - Encourage Everyone to Participate
  - Ask for Help or Clarification
  - Express Support and Acceptance
  - Offer to Explain or Clarify
  - Paraphrase Other’s Contributions
  - Energize the Group
  - Describe Feelings When Appropriate

- Formal Methods for Processing Materials
  - Summarize Out Loud Completely
  - Seek Accuracy by Correcting/Adding to Summaries
  - Help the Group Find Clever Ways to Remember
  - Check Understanding by Demanding Vocalization
  - Ask Others to Plan for Telling/Teaching Out Loud

Fermentation Skills

- Stimulate Cognitive Conflict and Reasoning
  - Criticize Ideas Without Criticizing People
  - Differentiate Ideas and Reasoning of Members
  - Integrate Ideas into Single Positions
  - Ask for Justification on Conclusions
  - Extend Answers
  - Probe by Asking In-depth Questions
  - Generate Further Answers
  - Test Reality by Checking the Group’s Work

Teaching Cooperative Skills

1. Help students see the need to learn the skill.
2. Help them know how to do it (T-chart).
3. Encourage them to practice the skill daily.
4. Help them reflect on, process, & refine use.
5. Help them persevere until skill is automatic

Ways of Processing

Positive Feedback:
1. Have volunteer students tell the class something their partner(s) did which helped them learn today.
2. Have all students tell their partner(s) something the partner(s) did which helped them learn today.
3. Tell the class helpful behaviors you saw today.

Group Analysis:
1. Name 3 things your group did today which helped you learn and work well together.
2. Name 1 thing you could do even better next time.

Cooperative Skill Analysis:
1. Rate your use of the target cooperative skill: Great - Pretty Good - Needs work
2. Decide how you will encourage each other to practice the target skill next time:

Start: “Tell your partners you’re glad they’re here.”
End: “Tell your partners you’re glad they were here today. Thank them for helping.”

References


Interaction Book Company
3028 Hallfax Ave S, Edina, MN 55424
(952)831-9500  Fax (952)831-9332
www.co-operation.org
Teaching Cooperative Skills

1. Help students see the **need** to learn the skill.
2. Help them **know how** to do it (T-chart).
3. Encourage them to **practice** the skill daily.
4. Help them **reflect on**, process, & refine use.
5. Help them **persevere** until skill is automatic.

**Monitoring, Observing, Intervening, and Processing**

**Monitor** to promote academic & cooperative success.

**Observe** for appropriate teamwork skills: praise their use and remind students to use them if necessary.

**Intervene** if necessary to help groups solve academic or teamwork problems.

**Process** so students continuously analyze how well they learned and cooperated in order to continue successful strategies and improve when needed.
Team Charter

- Team name, membership, and roles
- Team mission
- Anticipated results (goal)
- Specific tactical objectives
- Ground rules/ Guiding principles for team participation
- Shared expectations/aspirations

pp. 60-61, 204-205
Project groups are an effective aid to learning, but to work best they require that all groups members clearly understand their responsibilities to one another. These project group ground rules describe the general responsibilities of every member to the group. You can adopt additional ground rules if your group believes they are needed. Your signature on this contract form signifies your commitment to adhere to these rules and expectations.

All group members agree to:
1. Come to class and team meetings on time.
2. Come to class and team meetings with assignments and other necessary preparations done.

Additional ground rules:
1.

2.

If a member of the project team repeatedly fails to meet these ground rules, other members of the group are expected to take the following actions:

Step 1: (fill in this step with your group)

If not resolved:
Step 2: Bring the issue to the attention of the teaching team.
If not resolved:
Step 3: Meet as a group with the teaching team.

The teaching team reserves the right to make the final decisions to resolve difficulties that arise within the groups. Before this becomes necessary, the team should try to find a fair and equitable solution to the problem.

Member’s Signatures: Group Number:__________

1._____________________________ 3._____________________________

2._____________________________ 4._____________________________
Reflection and Dialogue

Individually reflect on rationale for Interactive (Cooperative) Learning and Teamwork. Write for about 1 minute.

- Context/Audience – Introductory Physics course
- Why cooperative learning and teamwork are important?
- What support do you have for your rationale?

Discuss with your neighbor for about 2 minutes
- Select/create a response to present to the whole group if you are randomly selected
Why Emphasize Cooperative Learning and Teamwork?

- Student learning
- Essential *transferrable skill* development
- Key to *innovation*
- High priority for *Employers*
Seven Principles for Good Practice in Undergraduate Education

Good practice in undergraduate education:

◦ Encourages student-faculty contact
◦ Encourages cooperation among students
◦ Encourages active learning
◦ Gives prompt feedback
◦ Emphasizes time on task
◦ Communicates high expectations
◦ Respects diverse talents and ways of learning

Discipline-Based Education Research (DBER) Report

Follow the Evidence

Discipline-based education research dispels myth about learning and yields results - if any educator would use it.

Last year, the National Research Council's Science Education Board examined Discipline-Based Education Research (DBER). They concluded that research evidence has the potential to improve teaching and learning in undergraduate science and engineering. The committee noted that, while some research has been conducted, there is still a need for more rigorous studies that can help educators understand what really works.

The committee's report highlights the importance of evidence-based teaching practices and provides examples of research studies that have been successful in improving student learning. They also emphasize the need for continued investment in research to further advance the field of discipline-based education research.

STUDENTS ARE CHALLENGED BY ASPECTS OF ENGINEERING AND SCIENCE THAT CAN SEEM EASY OR OBVIOUS TO EXPERTS.

- Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering
  - National Research Council
  - 2015


ASEE Prism Summer 2013

Nancy Kober
Cooperative Learning Research Support


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

Outcomes

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

* [CLReturnstoCollege.pdf]
Engaged Pedagogies = Reduced Failure Rates

Evidence-based research on learning indicates that when students are actively involved in their education they are more successful and less likely to fail. A new PNAS report by Freeman et al., shows a significant decrease of failure rate in active learning classroom compared to traditional lecture.

Freeman, Scott; Eddy, Sarah L.; McDonough, Miles; Smith, Michelle K.; Okoroafor, Nnadozie; Jordt, Hannah; Wenderoth, Mary Pat; Active learning increases student performance in science, engineering, and mathematics, 2014, Proc. Natl. Acad. Sci.
Conclusion. A strong body of research conducted over several decades has demonstrated that team processes (e.g., shared understanding of team goals and member roles, conflict) are related to team effectiveness. Actions and interventions that foster positive team processes offer the most promising route to enhance team effectiveness; they target three aspects of a team: team composition (assembling the right individuals), team professional development, and team leadership. (p. 7)
This is the story of these pioneers, hackers, inventors, and entrepreneurs – who they were, how their minds worked, and what made them so creative. It’s also a narrative of how they collaborated and why their ability to work as teams made them even more creative. The tale of their teamwork is important because we don’t often focus on how central that skill is to innovation.
The NACE survey also asked employers to rate **the skills they most value in new hires**. Companies want candidates who can think critically, solve problems, work in a team, maintain a professional demeanor and demonstrate a strong work ethic. Here is the ranking in order of importance:

<table>
<thead>
<tr>
<th>Competency</th>
<th>Essential Need Rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Thinking/Problem Solving</td>
<td>4.7</td>
</tr>
<tr>
<td>Teamwork</td>
<td>4.6</td>
</tr>
<tr>
<td>Professionalism/Work Ethic</td>
<td>4.5</td>
</tr>
<tr>
<td>Oral/Written Communications</td>
<td>4.4</td>
</tr>
<tr>
<td>Information Technology Application</td>
<td>3.9</td>
</tr>
<tr>
<td>Leadership</td>
<td>3.9</td>
</tr>
<tr>
<td>Career Management</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*Weighted average. Based on a 5-point scale where 1=Not essential, 2=Not very essential; 3=Somewhat essential; 4=Essential; 5=Absolutely essential

Designing and Implementing Cooperative Learning

Think like a designer

Ground practice in robust theoretical framework

Start small, start early and iterate

Celebrate the successes; problem-solve the failures
The Instructor's Role in Cooperative Learning

Make Pre-Instructional Decisions

Specify Academic and Teamwork Skills Objectives: Every lesson has both (a) academic and (b) interpersonal and small group (teamwork) skills objectives.

Decide on Group Size: Learning groups should be small (groups of two or three members, four at the most).

Decide on Group Composition (Assign Students to Groups): Assign students to groups randomly or select groups yourself. Usually you will wish to maximize the heterogeneity in each group.

Assign Roles: Structure student-student interaction by assigning roles such as Reader, Recorder, Encourager of Participation and Checker for Understanding.

Arrange the Room: Group members should be "knee to knee and eye to eye" but arranged so they all can see the instructor at the front of the room.

Plan Materials: Arrange materials to give a "sink or swim together" message. Give only one paper to the group or give each member part of the material to be learned.

Explain Task And Cooperative Structure

Explain the Academic Task: Explain the task, the objectives of the lesson, the concepts and principles students need to know to complete the assignment and the procedures they are to follow.

Explain the Criteria for Success: Student work should be evaluated on a criteria-referenced basis. Make clear your criteria for evaluating students work.

*Structure Positive Interdependence: Students must believe they "sink or swim together." Always establish mutual goals (students are responsible for their own learning and the learning of all other group members). Supplement goal interdependence with celebration reward, resource, role, and identity interdependence.

Structure Intergroup Cooperation: Have groups check with and help other groups. Extend the benefits of cooperation to the whole class.

Monitor and Intervene

Monitor Students' Behavior: This is the fun part! While students are working, you circulate to see whether they understand the assignment and the material, give immediate feedback and reinforcement, and praise good use of group skills. Collect observation data on each group and student.

Intervene to Improve Taskwork and Teamwork: Provide taskwork assistance (clarify, reteach) if students do not understand the assignment. Provide teamwork assistance if students are having difficulties in working together productively.

Evaluate and Process

Evaluate Student Learning: Assess and evaluate the quality and quantity of student learning. Involve students in the assessment process.

*Process Group Functioning: Ensure each student receives feedback, analyzes the data on group functioning, sets an improvement goal, and participates in a team celebration. Have groups routinely list three things they did well in working together and done thing they will do better tomorrow. Summarize as a whole class. Have groups celebrate their success and hard work.
Cooperative Lesson Planning Form

Subject Area: ____________________________ Date: ____________
Lesson: ________________________________

Objectives
Academic: ____________________________________
Social Skills: ______________________________

Preinstructional Decisions
Group Size: ______ Method Of Assigning Students: ____________
Roles: _______________________________________
Room Arrangement: __________________________

Materials:
◊ One Copy Per Group
◊ Jigsaw
◊ Other: ________________________________
◊ One Copy Per Person
◊ Tournament

Explain Task And Cooperative Goal Structure
1. Task: ______________________________________
   _________________________________________
2. Criteria For Success: _______________________
   _________________________________________
3. Positive Interdependence: ________________
   _________________________________________
4. Individual Accountability: ________________
   _________________________________________
5. Intergroup Cooperation: __________________
   _________________________________________
6. Expected Behaviors: ______________________
   _________________________________________

Monitoring And Intervening
1. Observation Procedure: ______ Formal ______ Informal
2. Observation By: ______ Teacher ______ Students ______ Visitors
3. Intervening For Task Assistance: ____________
4. Intervening For Teamwork Assistance: ____________
5. Other: ___________________________________

Evaluating And Processing
1. Assessment Of Members' Individual Learning: ____________
   _________________________________________
2. Assessment Of Group Productivity: ____________
   _________________________________________
3. Small Group Processing: ________________
   _________________________________________
4. Whole Class Processing: ________________
   _________________________________________
5. Charts And Graphs Used: ________________
   _________________________________________
6. Positive Feedback To Each Student: ____________
   _________________________________________
7. Goal Setting For Improvement: ________________
   _________________________________________
8. Celebration: ________________
   _________________________________________
9. Other: ___________________________________
Active Learning: Cooperation in the College Classroom

Informal Cooperative Learning Groups

Formal Cooperative Learning Groups

Cooperative Base Groups
Book Ends on a Class Session

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
Include "book ends" procedure

Are not as effective as Formal Cooperative Learning or Cooperative Base Groups
**Informal Cooperative Learning Planning Form**

**Description of the Lecture**

1. **Lecture Topic:**

2. **Objectives (Major Understandings Students Need To Have At The End Of The Lecture):**
   a. 
   b. 

3. **Time Needed:**

4. **Method For Assigning Students To Pairs Or Triads:**

5. **Method Of Changing Partners Quickly:**

6. **Materials (such as transparencies listing the questions to be discussed and describing the formulate, share, listen, create procedure):**

**Advanced Organizer Question(s)**

- Questions should be aimed at promoting advance organizing of what the students know about the topic to be presented and establishing expectations as to what the lecture will cover.

   1. 
   2. 
   3. 

**Cognitive Rehearsal Questions**

List the specific questions to be asked every 10 or 15 minutes to ensure that participants understand and process the information being presented. Instruct students to use the formulate, share, listen, and create procedure.

1. 
2. 
3. 
4. 

Monitor by systematically observing each pair. Intervene when it is necessary. Collect data for whole class processing. Students’ explanations to each other provide a window into their minds that allows you to see what they do and do not understand. Monitoring also provides an opportunity for you to get to know your students better.

**Summary Question(s)**

Give an ending discussion task and require students to come to consensus, write down the pair or triad’s answer(s), sign the paper, and hand it in. Signatures indicate that students agree with the answer, can explain it, and guarantee that their partner(s) can explain it. The questions could (a) ask for a summary, elaboration, or extension of the material presented or (b) prece the next class session.

1. 
2. 

http://personal.cege.umn.edu/~smith/