Tailoring Cooperative Learning Events for Engineering Classes

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Abstract

Faculty value high student engagement that leads to high learning outcomes. While high student engagement is frequently difficult to achieve, numerous studies have shown that cooperative learning events produce greater student engagement in a wide variety of disciplines. However, many students have had negative experiences with "group work" and are hesitant to participate. In addition, it can be unclear when creating a cooperative educational event for engineering classes whether it will work as planned. Our question is:

> "What are the important design features when tailoring cooperative educational events for engineering classes?"

We designed and applied fifteen distinct cooperative learning events while teaching an undergraduate materials science course of twenty-five students. Three separate instruments were used to collect student perceptions of the learning events and the data was then triangulated to determine and verify trends. The first instrument was a student survey immediately following each event to collect "snapshot" perceptions. The second instrument was an end of term activity in which each student rank ordered the individual events from "most helpful in learning," to "least helpful in learning." The third instrument was end of term qualitative data where the students described in writing what made the "most helpful" events helpful and the "least helpful" events least helpful.

We rated the events from excellent to poor based on the collected data. The spread of the event ratings allowed us to discover two important design features. (1) Design each event so that the students begin with the concepts and are guided through the application. This connection of the concept, application, and interrelationship between them greatly enhances learning. The learning environment is weakened when concept and application are taught separately. (2) Design each event so that students need to create and use visual elements in the learning. Student creation and subsequent use of graphs, sketches, or diagrams makes the learning more concrete and also facilitates collaboration.

Students overwhelmingly indicated that use of effective cooperative events enabled them to more easily master difficult material. The students did not consider effective cooperative events merely "group work."

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1. Introduction

"How can I (Steven Zemke) get my students engaged in material science?" This was a common frustration the first time I taught my introductory class. The course content was high and the students' motivation needed to be equally high—but wasn't. Furthermore, the lectures frequently seemed to fall flat—so an opportunity for learning would escape without being utilized. When the course was completed, several students thanked me for a "great class" and said they looked forward to taking more classes from me. Though my student evaluations were high, I was still unsettled. Did the students really learn much?

The following year I decided to teach the class using several cooperative learning events. Perhaps I could get the subject matter out of my hands and into the hands of the students by using cooperative learning events. Numerous studies have shown cooperative learning produce greater student learning and satisfaction than traditional lectures.

However, some students I know personally have told me about terrible experiences they had with cooperative learning gone awry. Poorly structured and implemented cooperative learning had not only been detrimental to their learning, but also down right painful. They hated and avoided classes with "group work." Though cooperative learning has been shown to be very effective, poor implementations abound! Our question thus is:

> "What are the important design features when tailoring cooperative educational events for engineering classes?"

During the Spring 2003 Quarter at Eastern Washington University I used 15 separate cooperative events in my introductory Material Science course. I collected student feedback with each event and also a summary at the end of the quarter to "hunt" for engineering specific cooperative education "best practices." The data indicated two central findings. First, events should be designed to teach concepts simultaneously with their applications. Secondly, events should incorporate student generated visual elements. Incorporating visual learning elements into a cooperative event is a natural way to teach both concepts and application together.

2. Literature review

2.1. Effect size

Many studies have shown that cooperative education produces greater learning than traditional approaches. Learning improvement is measured in effect size, which is the difference of the averages, measured in standard deviations, of a test group compared to a control group. Joyce and Weil cite Johnson and Johnson reporting the improvement by cooperative education:

> "The Johnsons' (1999) recent review estimated that, for the years over which several hundred studies have been accumulated, the average effect size on academic learning is about 0.61, which means that, on tests of academic learning, the average student engaged in cooperative learning…scores a little above the 70th percentile of students instructed in (individually) competitive circumstances." [1]

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Kanter[2] et al. report similar effect size when applying a cooperatively based inquiry method to prepare students for an engineering lab.

2.2. Requirements for effective cooperative learning

The literature contains a wealth of information on how to implement cooperative education. Johnson, Johnson, and Smith[3] describe five necessities to produce excellent results:

1. The students must have positive interdependence.
2. The students must have positive face-to-face interactions with their group members.
3. The students must be held individually accountable.
4. The students must be using functional social skills.
5. The instructor must insure that healthy group processes are working.

These five necessities all involve important interpersonal and group processes.

2.3. Task design strategies

Bean[4] lists several strategies for designing cooperative learning tasks. These strategies can be used to guide task design. His strategies that are readily transferable to engineering are listed below:

> "1. Think of tasks that would let students link concepts in your course to their personal experiences or prior knowledge.
> 2. Ask students to teach difficult concepts in your course to a new learner.
> 3. Think of problems, puzzles, or questions you could ask students to address.
> 4. Give students raw data (such as lists, graphs, or tables) and ask them to write an argument or analysis based on the data."

Hesketh, Farrell, and Slater[5] give a specific strategy for converting a laboratory exercise into a cooperative task:

> "To convert a laboratory write-up to an inductive style the following should be done:
> 1. Handout a prelab given to peak the students' interest. Have them hypothesize the trends in the data that will be collected.
> 2. The laboratory work should primarily consist of data collection and analysis using only graphical methods.
> 3. Discussion of the lab should take place in the classroom setting. Variable-parameter relationships should be identified.
> 4. Lectures on the variable-parameter relationships should be given.
> 5. Homework should be assigned based on the data taken in the laboratory."

2.4. General task design features

Several authors list general design features that cooperative learning tasks should include. The tasks should have clearly defined problem statement and deliverable[6], able to be completed in the given time period[6], given in written form[4], and open-ended[4].

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Hamelink, Groper, and Loson[7] suggest five higher-level features to design into cooperative tasks:

"1. Have several possible solutions.
2. Be intrinsically interesting.
3. Be challenging but doable.
4. Require a variety of skills.
5. Allow all group members to contribute."

2.5. Summary

Cooperative learning produces high outcomes when the student groups function with good interpersonal and group processes. The instructor needs to insure that these processes are operating. The instructor must also provide well-designed tasks or activities for the groups. Reasonable strategies for designing these tasks are described in a number of sources. General design features of these tasks are also described. In this present study we are seeking to identify design features specifically for engineering cooperative learning events.

3. Methods

3.1. Structure of the Study

The class met for four lecture hours and two lab hour per week for a ten week quarter. During the term, seven cooperative events replaced traditional lectures and eight cooperative events were used to begin the labs. The cooperative events fit into four broad categories: 1) practice using data, 2) predicting material behavior, 3) open-ended design problems, and 4) group decision-making processes.

Three distinct instruments were used to collect data: 1) post-event quantitative and qualitative surveys, 2) end of quarter ranking of all events, and 3) end of quarter qualitative student comments. Trends in the data from each instrument could then be further validated by comparison with data from the other instruments.

3.2. Cooperative event design

All of the cooperative events used the same general format and schedule. The event would open with a 5-minute explanation. The students would the form informal groups of four with those seated nearest and work on the task for 35 minutes. The class would then reconvene for student reporting and instructor summarizing.

The goals, tasks, methods, and additional necessary information were included on the handout. The handouts provided room for student work during the event. Figure 1 shows a typical handout for an event.

3.3. Post-Event survey

A short student survey was included on the backside of each event handout. Immediately following each event the students would individually complete and return the survey. Before the first few surveys, directions were given verbally and questions concerning the survey were answered. The survey asked the students to rate and give comments on their performance with

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the task and also to indicate the best teaching method for the concepts being learned. The same survey was used following each event. Figure 2 show a post-event survey.

Cooperative Event W6D1—Choosing steel and heat treatment.

1. This is a "think-out-loud" exercise—so think out loud.
2. Do not be afraid of making a mistake. This is difficult. Simply keep the flow of ideas coming and the critique of the ideas as well.
3. Choose a single person in your group to record the group ideas and to make sure each person contributes to the ideas.
4. Starting with the first part first brainstorm (and list) the important material properties for the part. Second, number the properties in priority order.
5. Similarly list possible material choices and possible heat treatments. Circle the best combination.
6. Give 3 reasons for the material and heat treatment choice.

Part Name	Part Use	Size/Tolerances	Important material properties for this design	Possible Material Choices: (low, med., or high carb)	Possible Heat Treatment Choices	Why did you choose your circled choices?
Stirring Beater	The beater quickly stirs an oil slurry. The slurry has many big lumps in it. The slurry also is 20% sand (very abrasive).	Open shape beater 3 feet in diameter with 4 inch sections. No close tolerances.				
Machine base	Several pieces of the machine bolt onto the base. The base will be fabricated by milling the part from a single block of steel.	Block shape 1 foot by 1 foot by 3 inches. Tolerances very tight.				
Nozzle	Replaceable nozzle that squirts out the slurry.	One inch diameter by one inch long. Nozzle must be replaced when the inner diameter wears a very small amount				

Figure 1. Sample cooperative learning event used during the study.

3.4. End of Quarter ranking and survey

At the end of the quarter each student was given copies of their own work in the cooperative events with their survey comments on the opposite side. The students were asked to rank order the events from "most helpful" to "least helpful" in learning industrial materials.

After ranking the events, the students were asked to complete a summary survey. The survey asked the students to comment on specific details that made events helpful or unhelpful, and to offer suggestions to improve the events. The ranked events were then returned with the surveys. Figure 3 shows the end of quarter ranking and survey form.

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1. Which teaching method would **challenge you to think most deeply** about these concepts and/or skills?
☐ Lecture ☐ Reading ☐ This type of event ☐ Homework Problems ☐ In-class examples

2. Which teaching method would **spark the most curiosity** in you about these concepts and/or skills?
☐ Lecture ☐ Reading ☐ This type of event ☐ Homework Problems ☐ In-class examples

3. Which teaching method would **most hold your attention** to learn about these concepts and/or skills?
☐ Lecture ☐ Reading ☐ This type of event ☐ Homework Problems ☐ In-class examples

4. Which teaching method would most make these concepts and/or skills **easiest to master**?
☐ Lecture ☐ Reading ☐ This type of event ☐ Homework Problems ☐ In-class examples

5. How much **previous experience** did you have **applying** these concepts and/or skills?
☐ Never applied this before ☐ Applied some of this before ☐ Applied all of this before

6. Rate how **difficult** these concepts and/or skills are:
☐ 1) Very hard to keep all concepts clear while working ☐ 2) With a bit of extra effort I could keep the concepts clear
☐ 3) Average amount of effort kept all concepts clear ☐ 4) This was very easy to keep the concepts clear

What specifically was difficult?
_____

7. Rate how well **this event kept you interested** in learning?
☐ 1) This event fueled my imagination ☐ 2) This event kept me on track ☐ 3) I had to occasionally keep myself on track
☐ 4) This event did not help me to keep on track ☐ 5) This event occasionally prevented me from keeping on track

What specifically was interesting?
_____

8. Rate **how relevant** these concepts and/or skills **seem** to your future education or career goals?
☐ 1) Highly relevant – easy to connect with my future ☐ 2) Relevant—can make some connections to my future
☐ 3) Irrelevant—no connection between this and my future.

What specifically was relevant?
_____

List any **"A-Ha'S"**:
_____

Figure 2. Student survey used after each cooperative event.

1. Sort the events in order from "most helpful" to "least helpful." "Most helpful" means that the event was most helpful in learning industrial materials. "Least helpful" means that the event was least helpful in learning industrial materials. "Most helpful" should be on top.

2. What specifically made the "most helpful" events most helpful? _____ …

3. What specifically made the "least helpful" events least helpful? _____ …

4. Do you have any suggestions of how to improve the use of these events? _____ …

Figure 3. Student ranking of events and survey used at the end of term.

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4. Results

4.1. End of the Quarter Survey Comments

The student comments were sorted into several broad categories. The choice of categories was driven by trends in the comments rather than being predetermined. Total number of students to respond in the major categories was tallied. The following are categories that received significant numbers of students responding. All students in the class of twenty-two responded.

Physical world, real life, and everyday relevant: Eight out of twenty-two students reported that the best learning events connected the concepts being learned to commonplace applications in the physical world. Either the event led to some hands-on learning or had direct reference to tangible physical properties of materials and their uses. One student expressed it this way: "Seemed to relate more directly with everyday life, how materials around us are impacted by temperature…."

Visual connection: Eight out of twenty-two students reported that cooperative events that included the use of visuals were quite helpful. The visual aspects of the events were student generated. One student wrote, "…actually drawing in the pearlite, ferrite, martensite pictures helped me to think and understand them…." Other students reported that the simple act of plotting data then using the graph to make decisions was very helpful to learn the concepts.

Working in groups: Seven out of twenty-two students reported that working in groups was very helpful. Most of these comments were blanket statements endorsing the use of groups, a couple of the comments indicated that bouncing ideas off of peers was helpful. Two individuals recommended having cooperative events more frequently (the class had about ½ of the lab time devoted to cooperative events and ¼ of the lecture time devoted to cooperative events). Two individuals reported that when the task became too difficult for their group, it became very frustrating.

Pre-lab prediction of results: Many of the labs began with events where the students were asked to predict a material behavior or structure. The material behavior or structure would then be tested in lab. Five out of twenty-two students reported that this was helpful: "The most helpful events were mostly associated with lab…because directly after doing them we were able to apply what we thought about or learned to actual events. We got to see if we were right."

Sufficient background: Six out of twenty-two students stated that sometimes they did not have enough background to effectively complete the learning task. The difficulty of the task exceeded their ability, and their combined group ability to feel confident in their work.

Clear directions: Five of twenty-two students reported that failure to give clear directions, clear processes, and specifically defined outcomes detracted from some of the learning events.

4.2. End of the Quarter Event Ranking

Each student ranked the 15 cooperative events from "best use of their tuition" to "worst use of their tuition." Table 1 tallies the percentage of students who rated each event in the top three

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events and lowest three events. By eliminating the middle events from the tallies we increase the contrast between "good" and "poor" events.

	Type	Event Description	% Rated "Top 3"	% Rated "Last 3"
In-class Cooperative Events	*Predict behavior*	*Motion of a dislocation*	11	44
	Data practice	*Stress and strain data*	28	22
		Nil-ductility data	38	0
		Fatigue data	40	7
	Open-ended design choices	*Choosing steel and heat treat*	10	5
		Choosing a ferrous casting and heat treat	23	18
		Choosing an aluminum alloy and surface treatment	11	28
		Designing with Acetyl Resin	21	16
Pre-Lab Cooperative Events	*Design sketches*	*Design testing machines*	15	25
	Predict behavior	*Movement of material in a hardness test*	27	9
		Tensile sample, procedure, and fracture appearance	18	9
		Predict heat treatment results	14	14
		Appearance of steel micro structures	23	14
	Team decision processes	*Choosing a composite material to investigate*	14	57
		Design a test suite for your composite material	16	42

Table 1. Percentage of students who rated each event in the "top 3" and "last 3".

Predict behavior—In-class event: In this event the students were asked to predict the movement of a dislocation. The event was not followed by a laboratory experiment or a discussion of plastic deformation of a material. Four times as many students rated this event in the last three as rated it in the top three.

Data practice: In these three events the students were given tabular data, asked to plot it, and then make a few design decisions based on the data. The 1st event of this type was rated equally often in the top three as the last three. The 2nd and 3rd events of this type were rated in the top three events more often than all other events and were rated in the last three events less often than any other event. The primary differences were 1) the highly rated events included a graph grid on the handout, 2) the lower rated event was too long for the allotted time, and 3) the students had much more familiarity and experience with the content in the lower rated event.

Open-ended design choices: In these four events the students were given a description of a part—its size and use environment—and asked to choose an appropriate alloy and heat treatment or surface finish. The student ratings on these events were split with equal numbers of students listing them in the top three events as in the last three events.

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Design sketches: The students were asked to "dream-up" and sketch material testing machines. Following the sketching of testing equipment the students examined actual equipment in the lab. About twice as many students rated this event in the last three as rated it in the top three.

Predict behavior—pre-lab events: In these four events the students were asked to predict a material behavior in a test or a material structure following a manufacturing process. The students immediately tested their predictions using lab equipment. The students rated these in the top three events about twice as often as in the last three events.

Team decision processes: The final two cooperative lab events led the students through group decision-making processes. These events were narrowly scripted and did not have any "technical" content. Students overwhelmingly rated these in the last three events.

4.3. Post Event Surveys

Following each event the students were surveyed on four categories: "previous experience," "difficulty," "interest generated," and "relevance." The following trends emerged from the surveys.

Least previous experience and most difficult: The three events in which the students reported they had the least experience were the same events the students cited as the most difficult. The events were "motion of a dislocation," "predicting heat treatment results," and "appearance of a steel micro structure." All three events are "predict behavior" type events.

Events that generated the most interest: The events that the students cited as generating the most interest were "choosing steel and heat treatment," "choosing a composite material," and "design a test suite for the composite."

Events considered the most relevant: The events "stress and strain data," and "Nil-ductility data" were rated the most relevant. Both events are "data practice" type events. The event rated third in relevance, but significantly lower than the first two, was "design testing machine."

The post event surveys also asked the students to compare cooperative event learning to learning by lecture, reading, homework, or in-class examples. The students were asked to make this comparison across the four categories of "Thinking deeply," "Sparking curiosity," "Holding the student's attention," and "Easiest way to master the material." For example, "What method of teaching would help you to *think the most deeply* about these concepts or skills. Table 2 shows the percentage of students who chose each teaching method by category. The percentages shown are averages over the events.

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Think most deeply					Spark most curiosity					Most hold your attention					Easiest way to master material				
Lecture	Reading	Cooperative	Homework	In-class example	Lecture	Reading	Cooperative	Homework	In-class example	Lecture	Reading	Cooperative	Homework	In-class example	Lecture	Reading	Cooperative	Homework	In-class example
3	3	75	3	16	4	2	72	1	21	2	3	70	2	23	8	2	62	3	25

Table 2. Aggregate student ratings of various teaching methods for four affective results listed by percentage of students.

5. Discussion

5.1. Cooperative Learning Events—Specific to Engineering

End of the quarter student comments indicate that engineering concepts should be taught ***simultaneously*** with the practical "real world" application. It is possible to design cooperative events that teach concepts at one time and then other events that teach the practical application at a different time. However, combining the two into single events produces a more powerful learning experience. This is not surprising since it provides the students both a context for understanding and a goal for application of the new knowledge.

Many students reported a strong desire to practically apply the material in they learned in the cooperative events. Verbiage such as "real world," "hands-on," or "everyday relevant" flowed through their comments. Comments of this nature were the most common answer to "what made the best events good?" A similar sub-theme that emerged dealt with predicting outcomes. Some students couched this in future terms as in predicting a failure or other outcome. Other students reported that witnessing a (self) predicted outcome helped them learn.

These comments do not explicitly demonstrate that teaching the concept simultaneously with the application of the concepts as necessary. The comments just as easily support the conclusion that students merely want the practical application without any conceptual framework. However, the student ranking of the events indicates that coupling the concept with the application is a better learning experience. The two events that were most frequently chosen in the "top 3" and least frequently in the "last 3" were "Nil-ductility data" and "Fatigue data." In both of these events, the students had to work from the conceptual understanding—starting with raw data—through the practical application of some design decisions.

Ranking of other events also support this premise. The "Motion of a dislocation" event was purely theoretical without much practical application and was ranked very low by the students. Alternatively, the four "Open-ended design choices" events were solely practical application, but were not ranked as highly as the events that spanned conceptual and practical application.

One very natural way to incorporate the conceptual and "real world" into a single cooperative event is to begin a lab with an event. Rather than having the students reenact a "scripted" lab, the students could first predict the behavior of the material in a test. In this way the students

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formulate their own hypothesis and then test to see if their predictions are true. Students commented in the end of the quarter survey that doing the pre-lab cooperative events helped their learning in lab. One student stated, "I also found the lab handout to be more thought provoking and interesting." This certainly indicates a better learning environment than the all too common dry, scripted labs.

Several students commented that ***incorporating visual learning*** elements into the events increased learning. The visual elements were student generated such as graphs or sketches. As one student wrote concerning an event, "This was a great visual exercise for the visual learner." The visual elements not only aid the visual learners, but also reinforce the visual nature of engineering.

Incorporating visual learning elements into a cooperative event is a natural way to teach both concepts and application together. One student commented, "I think the fatigue data event was helpful because it kind of went through all the steps from testing, to graphing the results, to interpreting the results, and helping us understand how to use the results to make good decisions." Many concepts are express visually and the extension to application is direct. The two events that were rated in the "top 3" most frequently and also rated in the "last 3" least frequently included visual elements while teaching concepts and application simultaneously. Though the ranking of these events does not differentiate which element (visual activity vs. concept simultaneous with application) is important, the end of the quarter comments indicated that both elements are important. The combination of these two elements makes a powerful learning environment.

The event "Stress and strain data" also incorporated visual elements to teach from concept through application. However, this event did not rate as high as the top 2 events even though it was very similar. This event differed in two primary ways that may explain the lower student response. First, the lower rated event was too long for the time allotted. Secondly, the handout did not facilitate the use of visual data. In the two highly rated events the handout included a simple charting area of grid lines; the lower rate event did not include the grid lines. During the events the students would often compare notes. The events with the pre-defined charting area enabled the students to work together (simultaneously with their own individual work) by simply glancing at each other's work.

5.2. Cooperative Learning Events—General Trends

Cooperative learning has been carefully researched for the past three decades. The literature reports that student learning and satisfaction are greatly increased using these approaches relative to traditional lecture. These studies have spanned many disciplines and educational levels. As expected, the majority of students in this study reported that working in groups was beneficial for them. The opportunity to bounce ideas off of each other led to more effective learning. As one student put it, "I think that since you had us work in groups that helped. We could all share ideas and really learn together. If you didn't know something then someone else would." Two students suggested that groups be used as often as possible. However, one student reported that his learning was not great enough to justify his time spent in the groups.

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The student ratings of cooperative events relative to lecture, reading, homework, and in-class examples also indicate that cooperative learning is more effective than traditional methods. Students overwhelmingly rated the cooperative learning as better in getting them to think more deeply, arousing their curiosity, holding their attention, and helping them to master the material easily. The ranking data is so overwhelmingly in favor of the cooperative events that it may be suspect. Some of this effect may be due to collecting the student responses within the context of the cooperative events. However, even if the positive responses are reduced somewhat to account for lack of student self awareness when reporting, the student preference for cooperative events was still very, very positive. Furthermore, the dynamics in the class during the events certainly indicated a high level of student involvement with the course material.

The student comments also highlighted another well known (if not obvious) necessity of cooperative learning—the learning must be properly scoped for the allotted time and the students' skills. Several students reported that when the task became too difficult for their group to accomplish, frustrations grew and the learning dwindled. Just as cooperative learning can be powerful when executed properly, the advantages turn to frustration if the intended outcomes are not achievable. This, of course, is true of most educational methods.

Further evidence that events need to be properly scoped is found in the student ranking of events (Table 1). One of the design choices events, "Choosing an aluminum alloy and surface treatment," was far too long for the time allotted. Though this event was essentially the same as the other design choice events, twice as many students ranked this event in their last three as ranked it in their top three events.

Students also commented that when clear directions, clear processes, and/or specifically defined outcomes were not given, their learning was deterred. This is another easy mistake to make when designing a cooperative event. The basic ground rules or boundaries within which the students were expected to work needs to be clearly delineated. One student expressed the problem this way, "(Cooperative events were least helpful when) they were vague, ambiguous, and you didn't know really what you were supposed to do or how to do it."

5.3. Other Trends in the Student Responses

The students overwhelmingly ranked the "Team decision processes" events very low. The first of these two cooperative events guided lab teams to decide what composite material they would make (from common hardware store items). The second event guided the lab groups in designing their own material qualification test suite for their composite material. During these two cooperative events the student teams floundered with the overall concept of team decision-making processes (brainstorming, multi-voting, etc.) and preferred to implement their own approaches.

One of the major complications in these "Team decision processes" events was that the events attempted to teach two very dissimilar skills at once. While the student teams were being asked to consider, "What composite material could you make from common hardware store materials?" they were simultaneously being asked to use specific and unfamiliar group processes. This may be the cause for the ineffective learning environment.

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6. Conclusions

Students rated two of the cooperative learning events in our class clearly above the other thirteen events. Student comments then provided insight into what made these events better than the other events. The following two design features, common to both of these two events, emerged as important.

1. Events designed such that students begin with concepts and are guided through application appear to produce a strong learning environment. The two highly rate events were both designed this way. However, events that stressed concepts without application or application without underlying concepts were rated significantly lower. Furthermore numerous student comments also indicate the importance of simultaneously teaching concepts and application.

We suspect that teaching the concepts side-by-side with their application gives the student a context for understanding the concepts and also provides insight for applying these concepts. Furthermore, we note that the ability to fluently move from concepts to application is fundamental to engineering.

2. Events designed such that students create and subsequently use the visual elements appear to produce strong learning environments. Several students commented that incorporating visual learning elements into the events increased learning. One student wrote, "I found the most helpful events to have charts, a 'solid' comparison for visual learning."

We suspect that facilitating the visual activities is important for real-time collaboration. The two highly rated events included a small, unlabeled graph area on the handout that allowed students to compare work with simply a glance.

Incorporating visual learning elements into a cooperative event is a natural way to teach both concepts and application together. Many concepts are express visually (such as graphed data) and the extension to application is direct.

Students overwhelmingly indicated that use of effective cooperative events enabled them to more easily master difficult material. Furthermore, the students did not consider effective cooperative events merely "group work." Though these student responses could not be triangulated with another measurement within this study, the frequency of positive response was truly significant.

7. Acknowledgments

We wish to express our gratitude to the authors listed in the literature section. We also express our gratitude to the many researchers who have investigated cooperative education the past several decades. Without their insights, efforts, and guidance our work would not have been nearly as fruitful.

I (Steven Zemke) also wish to personally thank the twenty-two students in my class for their enthusiasm and effort in providing me with their insights. Without their help this work would not be possible.

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Finally I wish to acknowledge the Engineering Technology and Multimedia Design Department at Eastern Washington University, and the chair Michael Brzoska specifically, for their openness to investigating new ways to instruct our students.

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