# Incorporating Leadership Training in a Sophomore Engineering Design Course

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**Abstract**

A novel course module to develop the interpersonal skills of engineering students is integrated into a sophomore design course. The module, entitled Professional Development I, provides students with background and training in communication, creativity, team dynamics, conflict resolution, leadership, values, risk taking, and personality types. The focus is on experiential teaching of practical applications and teaching methods are highly interactive. Professional Development I is part of Introduction to Engineering Design with students receiving 25% of their total course grade from the Professional Development portion and 75% from the engineering design portion. Within Introduction to Engineering Design, students are placed in teams and assigned a semester-long design/build/test project. A unique feature of the course is that the same teams who work together on their design project also receive leadership training

together. This allows instructors in interpersonal skills to tie concepts to the immediate experiences of the design team. There is close communication between engineering professors and leadership training instructors, who jointly teach the course. Introduction to Engineering Design is a requirement for all engineering students at Rensselaer.

**Introduction**

Practicing engineers need excellent leadership, communication, and teamwork skills to succeed in today's demanding business environment. At Rensselaer, engineering students improve their skills in these areas via a three-course Professional Development sequence. The first course of the sequence is normally taken in the sophomore year and is integrated with an engineering design course. The second course is aimed at junior level students and the final course is intended for seniors. Throughout the sequence, students learn through lectures, experiential exercises, readings, group discussions, and talks with invited guests. Topics include verbal and non-verbal communication, team dynamics, conflict resolution, leadership, values, vision, goal setting, and many others.

The focus of this paper is the first course in the sequence, Professional Development I (PDI), which has been a requirement for all engineering students since 1998. PDI is part of the sophomore engineering course Introduction to Engineering Design (IED). The PDI segment of the course accounts for nominally 1 out of 4 credits and contributes 25% to the course grade. The instructors for PDI are from the Archer Center for Student Leadership Development in the Division of Student Life at Rensselaer. The other 75% of the course focuses on engineering design, and is taught by

faculty in the school of engineering. Instructors from the Archer Center and from the School of Engineering collaborate on course design and implementation.

Throughout the semester, students work on a team charged with designing and building a prototype of a new device. The teams meet three times a week with an engineering instructor to develop and improve their designs and once a week with a leadership training professional to work on communication and team skills. There is close coordination between the faculty guiding an individual team.

Because PDI is part of an engineering design course, the topics in PDI can be taught in context rather than in isolation. As students struggle to work effectively on their engineering projects, they are exposed to relevant ideas and theories on team building, personality types, and conflict management. Often, PDI topics are discussed in light of specific experiences that the students report on their engineering team efforts.

The course is taught using an interactive methodology. Many topics are introduced through exercises designed to shake a student's preconceptions of the idea under discussion. Exercises are followed by a debriefing and discussion period in which students process the results of the exercise. Several self-assessment tools are used to help students gain personal insight. The level of feedback is high so that students internalize the material. Student participation in class is an important component of the course grade and no student is allowed to fade into the background.

Skills and topics covered in PDI include effective communication and feedback, managing personality differences, conflict management, risk-taking strategies, and ethical decision-making. Both written and oral communication skills are developed.

It is rare to find reports of leadership training courses integrated into engineering curricula. Many references exist for training professionals in effective communication using experiential exercises [1-3]. In addition, ways to teach innovation and creativity have been described [4]. Various survey instruments to help individuals in self assessment are also available and have been integrated into course topics. A good example is the Risky Business Quotations Sheet [5] which gives students perspective on their personal risk-tolerance. Finally, the dynamics of team behavior has been documented in many sources (see for example [7-8]).

**Syllabus**

**1. Communication skills**

In the first segment of the course, students examine communication concepts including the message sending process, the message receiving process, and nonverbal communication. An exercise in which students act on a sequence of verbal instructions [1] is used to stimulate thoughts about sources of miscommunication. The students are asked to fold, turn, and tear a sheet a paper in various ways without being able to ask questions or view the papers of neighboring students. Every student typically arrives at a different construction. This example of the errors that can occur in communication when feedback is restricted then becomes the stimulant for a discussion of the essential steps in effective communication. In the directions for the exercise, the orientation of the paper is purposely ambiguous. The point is made that sender and receiver may make different assumptions about the "proper" orientation. This leads to an analogy with professional

practice, where an engineer must be oriented to different cultures and to the perspectives of non-engineers.

Nonverbal aspects of communication including eye contact, physical spacing, and body language are illustrated by other examples. Students also explore the limitations in listening skills and learn through personal experience that a large fraction of spoken information is not automatically retained by the receiver. The effect of words, pace, and tone of voice on the emotive content of messages is demonstrated.

Students are coached in strategies for delivering effective feedback[2]. The difference between assertive and aggressive messages is highlighted. Techniques for depersonalizing the message, providing positive suggestions, and giving specific and descriptive feedback are introduced. Students are warned not to dwell on the past and thereby cause the listener to shut down.

Communication is illustrated through an exercise called "Blivet" [3]. Here two students are paired together, with one being the sender and the other the receiver. The sender has a construction formed from several pieces of paper of different shapes, as shown in Fig. 1. The receiver has an identical set of paper pieces, but does not know how they fit together. The sender must, using language only, explain to the receiver how to arrange the pieces properly. During this exercise, the receiver may not speak and cannot see the sender's construction.

Students struggle with this exercise and find it difficult to complete correctly. In the processing which follows the exercise, the idea of filters in communication is emphasized. A filter is the lens through which the communication is perceived. If the sender refers to a puzzle piece as being "shaped like Nevada" but the receiver is from

Turkey, the message may not get through. The filter of geographic background has screened out the communication. In one class, the sender described the construction as being shaped like a goat's tooth and the receiver was baffled. The cultural background filter had blocked the communication. If the sender describes a piece as having an angle of 135$^{o}$, but the receiver has little technical background, the message will not arrive. The construction in Fig. 1 is an upper case letter "T." In describing it, the sender will often say that it is shaped like the letter "T," but the receiver may imagine a lower-case "t."

This exercise leads to a long discussion about filters that arise in engineering work. The instructor might ask the class how they would feel if he or she came into class dressed in ripped jeans and a T-shirt. The answers vary from "cool, laid-back" to "doesn't care about the class." The important point is that clothing is not neutral; it sets up expectations in the receiver, before any overt message has been sent. Even a mechanical engineer and an electrical engineer have very different perspectives and may see a problem in a different light. Engineers must deal with people from many cultural and educational backgrounds, and learning to expect and avoid problems is essential to effective communication.

Among the greatest fears of students is giving a public speech. In PDI, students have many opportunities to deliver short speeches and are coached in effective public presentation. All aspects of the communication processes are addressed. Ways to capture the audience's attention at the start of a talk, to organize and develop concepts, to make smooth transitions between topics, to illustrate key points with examples and statistics, and to wrap up a talk with memorable concluding remarks are discussed and practiced. In addition, the mode of delivery is analyzed with reference to volume, pitch,

rate, pauses, and articulation. The use of visual aids and the effect of personal appearance, posture, and gestures are all considered.

A unique feature of PDI is that public speaking is tied directly to advancement in the engineering profession. Engineering students are likely to believe that they will be promoted solely on the basis of their technical skills and are often not motivated to become accomplished public speakers. PDI works to unravel that myth and emphasizes the role of effective presentation in technical leadership. In some cases, guests from industry reinforce the position of the instructor on this point.

**2. Creativity**

Innovation is a key aspect of engineering practice. The Latin root that gives us the word "engineer" also gives us words such as "genius," and "ingenious," which suggest creative ability. In PDI, students gain new perspectives on creativity and problem solving. Creativity is defined and the types and scopes of creativity and innovation are described. Examples of incremental (faster, bigger, smaller), breakthrough (refrigerators, digital cameras), and transformational (gunpowder, telephones, the Internet) innovations are discussed in small groups and then reported to the entire class [4].

In this segment, students often complete a brainstorming exercise. For example, each team is asked to list all the ways they could use a light bulb. No critical judgments are permitted and freewheeling is welcomed. The quantity and not the quality of ideas is emphasized and combination and improvement of ideas are encouraged. Through similar

exercises, students are exposed to other techniques for stimulating creativity, such as mind mapping, storyboarding, and problem reversal. An example of a mind map for the light bulb exercise is given in Fig. 2.

In brainstorming, students are asked to hold judgment at bay while ideas are freely aired. For example, in the mind map of Fig. 2, the property of heat generation is noted. One student suggested that a light bulb could be used to toast marshmallows on a camping trip. Expressing flippant ideas like this should not be discouraged, since they sometimes lead to good ideas. A marshmallow-toasting light bulb may not be practical, but it did stimulate the reasonable idea of using a light bulb to power a toy oven.

In problem reversal, a positive statement is changed into a negative one. For example, students may be asked to list all the ways that customer service could be worsened. This alone will generate ideas on how to improve service. Or desired results could be flip-flopped. If you want to increase sales, what would you have to do to decrease them?

Another guide to students is the "killer phrases" list. Here 60 sample statements guaranteed to suppress creativity are listed. They include "We tried that before," "That's not our problem," "I don't see the connection," and "Good thought, but impractical." Students will often recognize these and relate them to the experience they have had with their engineering design team.

Creativity is presented at the point in the semester when teams are initiating their new designs for Introduction to Engineering Design. The links between the two parts of the course become very apparent and motivating. To further emphasize the importance of creativity, examples of corporate efforts to nurture creativity are presented and

discussed. Cross-functional teams at Ford and Motorola, open door policies at Sony, and creativity centers at Lucent, as well as many other examples are included.

**3. Risk**

Closely linked to creativity is risk and the willingness to accept it. Students are asked to select phrases from the Risky Business Quotations Sheet [5] that best reflect their attitude toward their academic future. They then self-identify as high, medium, or low risk takers. The instructor supplies a framework for thinking about risk. It includes assessing the potential gains and losses and estimating the uncertainties involved. Three strategies for reducing the impact of risky decisions: sharing the risk with others, limiting the possible losses, and diversifying, are identified. [6]

**4. Team Development Theory**

In recent years, industry has made a major shift from traditional hierarchical management to team-based production. Students are prepared for this new environment through theoretical ideas, experiential exercises, and self-assessment surveys. Team Player Styles are discussed, including the Contributor (a dependable, task-oriented person), the Collaborator (a goal-oriented, big-picture person), the Communicator (a process-oriented, "people" person) and the Challenger (a questioning, risk-taking person). Students are given the option to complete a survey to identify the role they play on their design team. The results are compiled and discussed in small groups. The theory is tied to behaviors that students have witnessed on their own teams. This exercise stimulates

self-reflection and helps students to see themselves and team member in a different and more positive light. Finally, the results of discussion are shared in the large group.

Tuckman's stages of team development [7] (Forming, Storming, Norming and Performing) are described in detail. As a forming exercise, students are asked to complete the following sentences:

1. An important technological invention is…
2. Something I want to accomplish with this team is…
3. Two of my goals for this team are…
4. Something you should know about working with me is…

Students also complete a survey on attitudes toward working on a team. This opens avenues for discussion and allows students to put issues on the table.

The team-building segment of the course is topped off with an adventure-based [8] exercise in which students in teams solve a simulated problem. For example, in the toxic waste exercise (which is performed in a gymnasium), two large circles are drawn on the floor. An empty canister sits at the center of one circle and a canister filled with popcorn kernels sits at the center of the other. Each team is given two long ropes and a bicycle inner tube cut in half. Their task is to transfer the kernels (which represent toxic waste) from one canister to another without entering the circles. The exercise is difficult, because no part of a student's body may enter the region directly above the circle. If a student's arm inadvertently enters the forbidden zone, he or she incurs a penalty for a short time and is not available to assist the team.

After the exercise is over, students meet with the instructor to reflect and discuss. The questions that are most relevant for that particular team are introduced. These might

include: How did you generate solutions? Did one or several individuals make decisions? On a scale of 1-10, how committed were you to executing the plan? What are some of the examples of when you received feedback during the session?

This exercise is very popular and induces students to open up in ways that they will not as members of the design team. A student might complain, "You started bossing people around" or "you are a mechanical engineer, you should know about this." The toxic waste exercise occurs early in the semester, and allows the instructor to learn about team issues and work on resolving them.

**5. Conflict**

A structure within which to understand team conflicts is presented. Several levels of conflict are defined with higher levels being more difficult to resolve. These levels are conflicts over:

1. Facts or data
2. Process or methods
3. Goals or purpose
4. Values

For example, suppose the issue is global warming. A conflict over facts might involve the chemical mechanisms that occur in the upper atmosphere. A conflict over process might entail the various methods of restricting emissions – add scrubbers, use alternate fuels, drive less, etc. A conflict over goals could center around what targets to set for acceptable emission. Finally, a conflict over values may revolve around who should pay for reducing emissions.

Students then make the leap between examples like these and their engineering team experiences. The most difficult conflicts to resolve are those centering on values. For example, one team member may want an "A" in the course, while another is content to just pass. An electrical engineering student may want to add microprocessors while a mechanical engineering student may see that as "unnecessary bells and whistles." Less difficult, but still taxing, conflicts arise over when and how long to meet, and who should be in charge.

Students typically have a knee-jerk response to conflict. If, for example, a conflict arises over a team member not contributing to the design, students often respond by either doing the work themselves, becoming angry, or blaming the other team member and then taking over. They rarely use constructive strategies in solving the problem. To correct this, teams are introduced to [Kilmann's] strategies for managing conflict including avoidance, accommodation, compromise, competition, and collaboration. The time to use each strategy is discussed and illustrated through a case study (Zach's Electrical Case) [9]. Small groups are also asked to generate conflict scenarios which typically occur on their engineering design teams and then discuss the conflict in light of the framework that has been presented.

**6. Myers-Briggs Type Indicator**

The Myers-Briggs type indicator [10] is a self-assessment instrument that characterizes normal personality differences. It explains basic patterns in human functioning and sheds light on team activities and conflicts. Individuals are scored along four different dichotomies – Extraversion-Introversion, Sensing-Intuition, Thinking-

Feeling, and Judging-Perceiving. PDI instructors are trained in administering and processing the Myers-Briggs and have been qualified by the Association for Psychological Type. Students are invited rather than required to fill out the survey, but there are normally no objections. Although the Myers-Briggs indicator identifies individuals as a particular type, the instructor emphasizes that everyone can access behaviors of both preferences of a dichotomy. It is just that a particular person often prefers one style over the other. The Myers-Briggs type indicator is often used in industry to help teams function successfully.

After the students have filled out the type indicator, qualified instructors divide them into groups according to type [10]. The first dichotomy is Extraversion-Introversion. Extraverts focus attention on the outer world and get their energy from interacting with people and taking action. Introverts prefer to focus on their own inner world and receive energy from reflecting on thoughts, memories, and feelings. Extraverted students move to one side of the room and introverted students take the other side. Sitting in small groups, each side is invited to ask the other questions about their behavior at meetings. The extraverts ask "Why are you so quiet in meetings?" "Why do you look so bored?" The introverts ask, "How can you talk all the time?" There is a large measure of humor and laughter. The instructor then asks what happens on a team when there is a mix of introverts and extraverts. The extraverts claim, "We take over." The introverts say, "We are exhausted. It's hard to get a word in edgewise." Leaders on teams must be sensitive to the needs of both extraverts and introverts. They must allow time for the introverts to reflect and opportunity for the extraverts to work through their

ideas out loud. The course teaches respect for both types and encourages students to be sensitive to these personality differences.

The next preference is the Sensing-Intuition dichotomy. Sensors like to take in real, tangible information. They observe specifics and practical facts. Intuitives focus on the big picture and are interested in abstract ideas and patterns. The students are divided so that each table is populated with either all sensors or all intuitives. Then the instructor places an apple on the table and asks "Tell me about this."

The sensors describe the apple as round, red, and McIntosh. They talk about the stem, the leaf, the weight, the size, and any bruises. They will probably read the sticker, if there is one. The intuitives also describe the apple as red and McIntosh, but they quickly leap to stories about apples. They may discuss William Tell, bobbing for apples at Halloween, or making applesauce. As different tables report their observations, students immediately see the differences.

Sensors and intuitives can encounter conflicts in a team setting. Sensors often view intuitives as wasting time. Intuitives may see sensors as unimaginative. For example, an intuitive may want to focus on the overall design of a new frame for an all-terrain vehicle. A sensor might be concerned with how fasteners will attach to the frame, while, to the intuitive, that is just a minor detail that will be worked out in the end.

The third dichotomy in the Myers-Briggs type indicator is Thinking-Feeling-deciding. Thinkers are logical and analytical and believe that fairness means treating everyone equally when making decisions. By contrast, feelers tend to be empathetic and guided by personal values during decision making. To them, fairness means treating everyone as an individual.

The final axis on the Myers-Briggs scale is Judging-Perceiving. Judgers prefer to live life in a planned and organized way. They are energized by getting things done. Perceivers prefer to live life in a spontaneous and flexible way. They are energized by adapting to the demands of the moment. Judgers don't want Perceivers on their teams and are intolerant of their last-minute work habits. Perceivers see Judgers as inflexible and up-tight. Through discussion, students see the value of having both types on a team. Each preference is effective given the right circumstances and each contributes to the success of the team.

**7. Values and Ethical Decision Making**

In the final weeks of the course, discussion centers on values and on how values influence team performance. Students typically struggle with this topic. They acknowledge that each individual has different values, but they do not understand how values relate to engineering design. Values are not inborn, but are developed over time. Students are introduced to the stages of values development: acceptance, preference, and commitment. Then the instructor introduces a list of ten possible values, such as integrity, cooperation, family, fairness, friendship, etc. Students are asked to individually identify their top 3 or 4 highest values and their bottom 3 or 4 lowest values. A discussion follows in which students explain how their behavior demonstrates their values. For example, if someone values family over work, he or she may not want to miss a child's piano recital, even though an important work commitment must be postponed.

Students are informed that corporations have value systems. These may be reflected in the corporate mission statement or posted on a web page. Values can be important at a job interview, especially with the recent emergence of behavior-based interviewing methods.

Values determine how much time an individual student commits to the design project and how much money he or she is willing to spend. The values of the professor may strongly influence the team. Some professors value a creative and risky design, which may not perform as expected, while others prefer, above all, a prototype that works. Talking about values does not change them, but it does allow the possibility of accommodation. It can explain team dynamics and lead to the willingness to adjust.

The last topic in the course is ethical decision making. The distinction between ethics and values is emphasized. Ethics refers to standards of conduct based on moral duty or virtues and is derived from ideas about right and wrong. Engineering societies publish codes of ethics designed to protect the public from unsafe designs or harmful engineering decisions. The requirements that ABET sets for education in ethics is explained to students. Examples of how time or money crunches can lead to unethical engineering decisions are given.

Students frequently believe that ethics are black and white, either right or wrong. To challenge this view, the students are guided in the Ethical Barometer exercise. First, a scenario in which a student copies a term paper from your roommate and submits it as her own is described. The student has just helped you with a major campus event and claims that she therefore did not have time to write a paper of her own. Students who would definitely report the incident to the professor are asked to stand at one end of the room

and those who would definitely not report the incident stand at the other end. Students who are unsure are encouraged to take a spot somewhere between the endpoints according to the strength of their opinions. Then more information is added. The student will lose her scholarship if she is caught. Students are allowed to shift their position if this new datum influences their opinion. The roommate is your best friend and could be seriously hurt by being implicated in cheating. Again students shift. The process is repeated with many additional bits of information. During the exercise, discussion and explanations for the position taken are aired. In the end, students tend to agree that it is not at all black and white, but that ethical decision-making can be complex and difficult.

Many times students face ethical dilemmas while working on their teams. A typical problem is the student who does no work and wants another to cover for him or her. Often, students want to ignore the problem. They close their eyes to the infraction, do the work themselves, feel angry or victimized, and blame the concept of teamwork for their difficulties. The course encourages them to find an alternate approach; one that allows them to work through the problem with the non-performing student and not to just "let it go."

**Course Structure and Organizational Details**

As mentioned earlier, the professional development topics form one part of a sophomore engineering design course. Each student's schedule in this course is as follows:

-attend a weekly lecture with about 300 students for two hours

-meet the professional development instructors once weekly in groups of about 28 for a two hour session

-meet the engineering professor in groups of about 28 for two 2-hour sessions per week

Grades in the professional development portion of the course are based on performance on two exams, which test both theory and ability to apply the theory in engineering situations. An in-class presentation is required. In addition, two take-home assignments form 30% of the grade. Attendance and class participation make up 20% of the final grade.

Professional development and engineering instructors work closely together during the semester to ensure team success. If a particular team is having difficulties, the instructors exchange information and work together to resolve problems. The engineering instructors visit professional development classes on occasion and vice versa. The entire course is financially supported through the engineering school.

**Assessment**

Professional Development is a requirement for all engineering students. It is the only named requirement in the engineering curriculum outside of courses in engineering, science, and mathematics. The response of students to PDI typically falls into three groups. Some find the material to be enriching, to open new perspectives on human behavior, and to be important to their goals. A second group participates willingly but is relatively uninterested in the course because they are unsure of the relevance to engineering practice. There is a group who rebels against the ideas presented, often

labeling them as “obvious” and unimportant. These students are still at the point of believing that engineers can succeed merely on technical merit without developing interpersonal skills and abilities. The situation shifts after students progress to the senior level Professional Development III course. Many of them have, at that point, completed assignments in industry and are now much more attuned to the requirements of the engineering workplace. Most are enthusiastic participants in Professional Development III.

An end-of-semester survey of students is used to assess the course and to guide future development. Composite survey results for six sections of Professional Development I including 175 students are given in Table 1. In general, students agree that they have expanded their knowledge base in teamwork-related topics and that they have had the opportunity to practice these skills. They also report increased self-awareness and understanding of factors affecting team performance. There are also some gains in communication ability and the ability to apply ideas to actual team experience, but these gains are modest. Overall, students have a positive attitude and have at least begun to understand the complexities of working on teams.

**Summary and Conclusions**

Although the topics in the course are necessarily presented in a specific order, in fact, every topic relates to every other in some way. Values lie behind communication and personality type is related to values. Throughout the course, the instructor weaves the connections between topics and reiterates important points raised earlier. Students often begin the course with the attitude that “if a team member is not pulling their weight,

they should be fired." At the end of the course, they begin to understand that "difficult" people are rarely fired in the industrial setting and that conflicts need to be addressed and resolved by less drastic means. For many, the course is their first introduction to team dynamics.

It is important for students to have this experience early in their college career. Many students are resistant to the ideas presented, and require multiple exposure as well as actual industrial experience before they begin to appreciate the importance and value of the course topics. This is especially true of the students who enter the course with low interpersonal skills.

Students leave the course with increased skills in communication, creativity, and risk-taking. They have a foundation for understanding team development, conflict resolution, personality preferences, values, and ethical decision making. All of these topics are important components of a successful career in engineering.

| | |
|---|---|
| I learned about theories and concepts related to teamwork | 4.1 |
| I learned about skills needed for effective teamwork | 4.0 |
| I was given the opportunity to practice teamwork-related skills | 3.8 |
| I have stronger self-awareness of my own attitudes toward teamwork than I did before I completed this course | 3.5 |
| I have a stronger knowledge now of the factors that affect team performance than I did before I completed this course | 3.8 |
| I have a stronger awareness of the impact of personality differences on team performance than I did before I completed this course | 3.8 |
| I have a stronger knowledge of skills necessary for effective communication than I did before I completed this course | 3.4 |
| I have a stronger knowledge of the skills needed to be an effective public speaker than I did before I completed this course | 3.1 |
| I have a stronger knowledge of the stages of team development than I did before I completed this course | 4.0 |
| I have learned about tools to manage conflict after completing this course | 3.4 |
| I am more aware of the tools available to foster creativity and promote calculated risk-taking after taking this course | 3.2 |
| I am more aware of my own values and how they impact my interaction within a team setting than I was before I took this course | 3.4 |
| I was able to apply what I learned in this course to my IED team experience | 3.3 |

Table 1. Average survey results for Professional Development I, Fall, 2001.
1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree

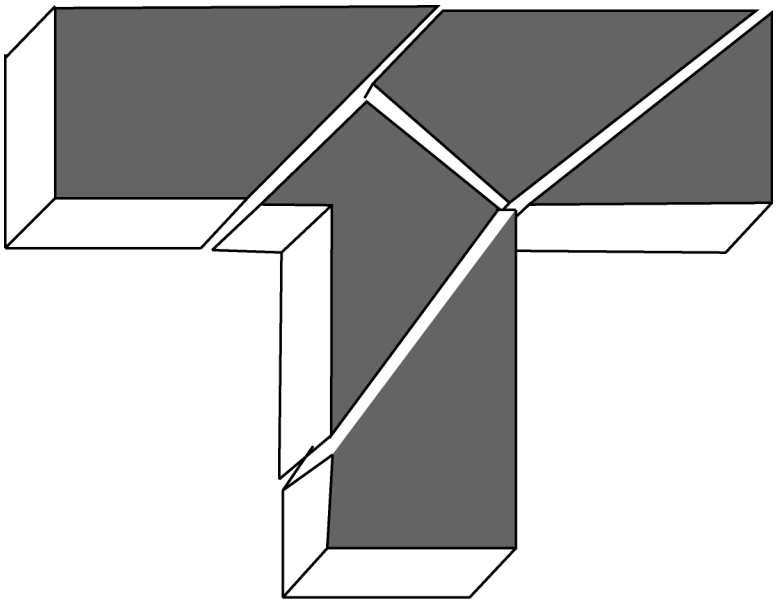

Figure 1 Construction used in the communication exercise Blivet

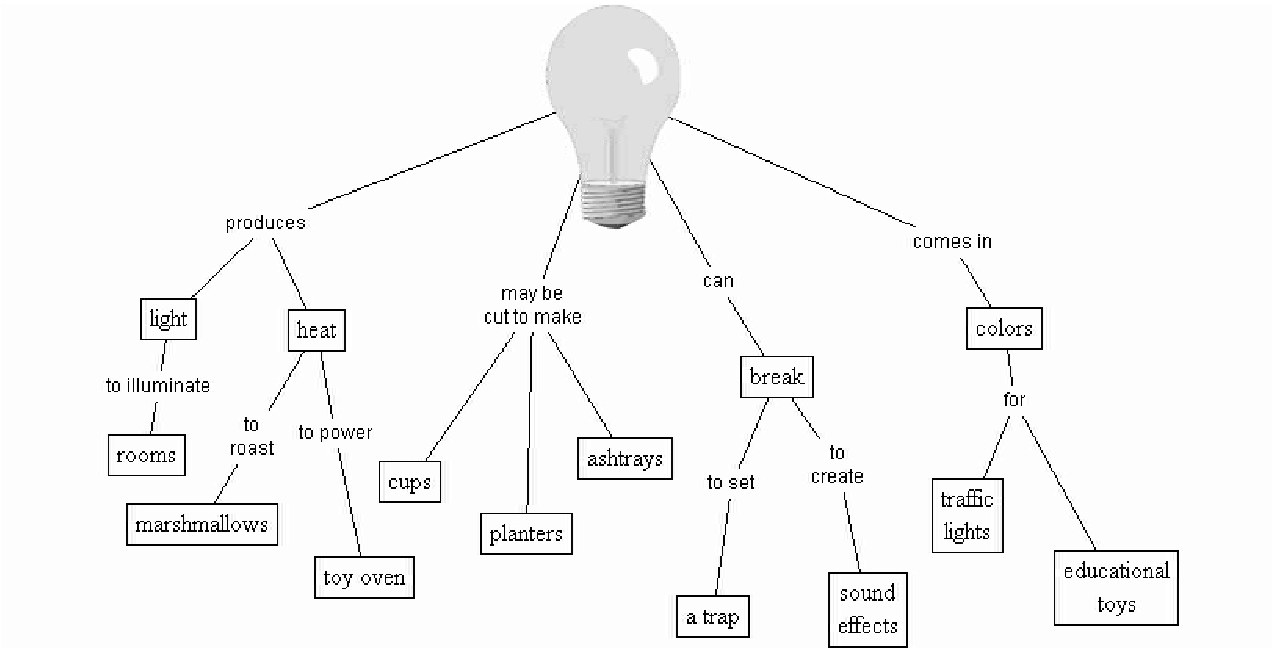


Figure 2. Example of a mind map for use in creativity exercises

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