THE IMPORTANCE OF LEARNING STYLES IN GROUP DESIGN WORK

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Abstract *- Effective communication between engineering design team members is essential. It depends on successful transfer (sending, receiving and processing) of information. This information may range from data and facts to creative ideas. Recent work by Felder and Silverman has shown that individuals differ from one another in how they prefer to receive and process information. In this paper we look at the relationship between individuals' preference for receiving information and their methods of sending information. It was initially anticipated that each individual's mode of presenting information would match his or her preferred mode of receiving information, and that this match would result in improved communication.*

To study the congruency (or incongruency) of how individuals prefer to receive information and how they go about sending information an experiment was designed and conducted. The experiment consisted of four teams of engineering educators engaged in a design exercise. Their design activities were videotaped.

Results based on analysis of the tapes and individual Learning Styles Inventories show that most participants preferred to receive information visually and engaged in drawing very little during the design exercise. If the definition was expanded to include using drawings, communicative gesturing (i.e., using hand gestures to describe a physical object or action), using hardware, and referencing hardware, visual communication went from comprising an average of 3.8% of the design time to an average of 21.1% of the design time.

NOMENCLATURE

We offer below working definitions for words used throughout this study.

***Communication*:** The exchange of information between individuals.

Visual Communication: Communication that leaves the trace of an image in the mind of the receiver. Including but not limited to drawings, gestures and demonstrations.

Verbal Communication: Communication that leaves the trace of a linearly ordered sequence of words in the mind of the receiver. Including but not limited to written and spoken words and mathematical formulas.

Idea: An internally formed thought or opinion.

Conceptual Phase of Design: The phase of the design process during which the problem space and the solution space are explored.

RESEARCH OBJECTIVES

Motivation

"The Engineer or Engineering Student should be able to … 1. Communicate, negotiate, and persuade…" - Sheri D. Sheppard and Rollie Jenison [1]

The above quotation is from a list compiled by Sheppard and Jenison, based in part on ABET criteria, entitled *"Qualities expected in a design engineer and that engineering courses should be helping engineering students to develop."* The ability to communicate is especially important during the conceptual phase of design. It is during this period that designers are gathering information and generating ideas. The ideas reside in the minds of the individual designers and must be communicated to team members before they can be discussed, built upon, refined, and evaluated. Consequently, communication of a large amount of information occurs.

Effective communication depends on the successful transfer (sending, receiving, and processing) of information. This information can be represented in many different forms from very abstract conceptual ideas to quantitative data. An opportunity to improve communication arises if we recognize that individuals deal with information differently.

Learning Style

Recent work looks at the different ways in which individuals prefer to receive and process information. Felder (Richard Felder, professor of Chemical Engineering at North Carolina State University), has identified five dimensions related to learning styles along with the poles of each dimension: Perception (sensing, intuition); Information Reception (visual, verbal); Information Organization (inductive, deductive); Information Processing (active, reflective); Information Sequencing (sequential, global) [2].

Felder went on to develop an *index of learning styles* [3] that determines, based on responses to 44 questions, the learner's preferences relative to four of the dimensions. Felder is careful to note that everyone uses both poles of any particular dimension, but that we each tend to favor one pole over the other. He found that the learning styles of engineering faculty and undergraduate students (based on self-assessments) were similar with regard to the Information Reception Dimension (with both groups

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reporting a preference for "visual" learning), and the Information Sequencing Dimension (with both groups reporting a preference for "sequential" learning). These two groups differed on the Perception Dimension (with more students than faculty reporting being sensing learners) and on the Information Processing Dimension (with more students than faculty reporting being active learners) [4] [5] [6].

Figure 1 shows a sample profile of an individual with a moderate preference to receive information visually.

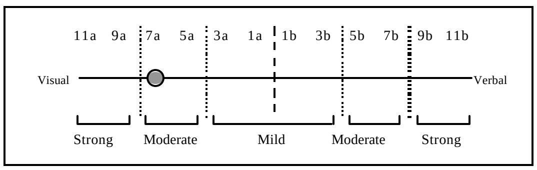

Figure 1. Information Reception Dimension (sample profile)

EXPERIMENTAL APPROACH

Experimental Goals

The first goal was to design an experiment to address the following question; given knowledge of how an individual prefers to receive information, can anything be known about how they will prefer to present information? It was desired to form teams based on the strength of their preference for receiving information and observe the communication patterns. It was expected that teams composed of individuals with similar preferences would exhibit communication that matched those preferences.

A second goal was for the participants to operate in the conceptual phase of design. The individuals were not allowed to interact with the hardware building kit during the analyzed portion of the experiment. We were concerned that by having the actual hardware, participants would start prototyping the first conceived solution and neglect the generation of alternate solutions.

Subject Population

The subject group was composed of assistant professors in various engineering disciplines who were participating in a summer workshop at Stanford University. Twelve of the thirty two participants taught in Mechanical Engineering departments with five actually teaching courses that involved design. Most participants were in their mid-thirties and more than a third had some amount of industrial experience. [7]

Team Selection

Teams were formed using three criteria. The first of these was based on Felder's Learning Styles (LS) inventory [5] related to the Information Reception dimension (visual or verbal). LS inventories were administered to the participants the day before the design exercise. The distributions of participants' Information Reception dimension are shown in Figure 2.

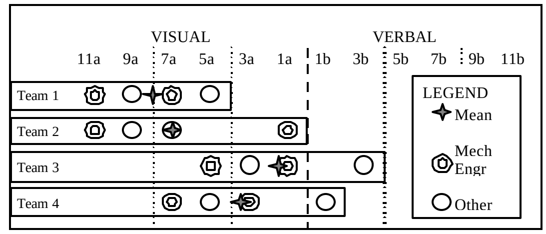

Figure 2. Participant LS distributions

Team 1 was formed such that its members, on the average, strongly preferred to receive information visually. Team 2 had a moderate preference to learn visually. Both Team 3 and Team 4 had a mild preference to receive information visually.

Very few of the participants had a preference to receive information verbally. This is consistent with Felder's finding that most science students are visual learners. [5]. This trend has also been confirmed in LS profiling of student designers, design researchers, and professional engineers [8].

The second criterion used for team formation was that each team have equal gender representation. This was important because it was desired to observe the natural communication patterns of the participants. It was felt that having one dominant gender in the team might inhibit the minority gender's pattern of communication.

The final criterion was that each team have at least two mechanical engineering professors as members. This was due to the nature of the task, which involved building a device that would likely use gearing and other component configurations that mechanical engineers are more familiar with than members of other disciplines.

Design Exercise

The teams engaged in the "Bodiometer Design Exercise." The goal of this exercise was to design and build a device, using components of a Lego™ Technics set, that would traverse the contours of the human body and take four qualitatively different measurements: wingspan, hand profile perimeter, chest and head circumference.

The exercise was divided into three segments. The first segment lasted thirty minutes and involved purely conceptual design; the participants were given the exercise instructions, pens, pencils, paper, and the unopened box of Lego™s. They were allowed to look at the Lego™s but were not allowed to take them out of the box. During the second segment the teams had seventy-five minutes to prototype and document their design. Teams trained an operator in the use of their device during the third segment and the operator performed the four measurements [9].

Data Collection and Preparation

Videotapes of Teams 1-4 were made during the first segment of the exercise. All working notes and drawings that the team put down on paper during this phase of the design were collected. A final calculated score, based in part on aesthetics, accuracy and measurement time, was recorded for each teams' device. These three evidences, along with the LS inventories for each participant comprised the data set for each team.

During a preliminary viewing of the videotape it was determined that the audio from two of the four teams, Team 2 and Team 3, was unsatisfactory for the purpose of analysis. The audio of the remaining two teams was then transcribed. Each instance of a new speaker was time stamped and from that the length of each statement was determined.

DATA ANALYSIS

Mapping Team Activity

Videotape is a very rich form of data and the choice of an appropriate analysis scheme is dependent on the questions that the analysis is designed to answer. In order to verify that the teams were engaging in conceptual design, the analysis scheme proposed by Atman (Cindy Atman, director of the Center for Engineering Learning and Teaching at the University of Washington) was used. With this scheme statements are classified based on different activities that designers traditionally engage in during the design process [10]. A listing of the activities that occurred in the videotape data, only a partial list of the entire analysis scheme, is included as Figure 3.

Two modifications to the scheme were needed. One modification was necessary because Atman's studies were of verbal protocol data of single subjects engaged in a design exercise while data in the current study were of teams of designers. Specifically, the Communication code was redefined to be limited to the describing of the design to those outside the group through documentation or face-to-face communication. A second modification was necessary because of the purposeful ambiguity of the design exercise. The Information Gathering code was redefined to include requests for process as well as task specific information.

A section of the transcripts was encoded by one of the authors and an independent researcher. The analyses were compared and any discrepancies were argued through to consensus. Following this calibration, the entire length of the two transcripts was encoded. Samples were taken at each minute interval and the resulting activity was displayed graphically to produce a map of the patterns of activity.

Analysis scheme for experiment

Coding	Description
Identification of Need	Identify basic needs (purpose, reason for design)
Problem Definition	Define what the problem really is, identify constraints, identify criteria, reread problem statement, question the problem statement
Information Gathering	Searching for and collecting needed information (*modified from Atman*)
Generate Ideas	Develop possible ideas for a solution, come up with ideas, list different alternatives
Modeling	Modeling, describe how to build the idea, how tc make it, measurements, dimensions, calculations.
Feasibility Analysis	Determining workability, verification of workability, does it meet constraints, criteria, doe it make sense, etc.
Communication	Define the design to others, write down a solutio or instructions (*modified from Atman*)
Other	This code is used when none of the above codes can be applied.

Figure 3. Activity Mapping Analysis Scheme (from [10])

Mapping Visual Communication

The next stage of the analysis was to determine how much visual communication occurred. Each instance of drawing was noted and time stamped. The numbers were surprisingly small (as discussed in the results section), especially considering that all but two of the participants preferred to receive information visually. However, repeated viewing of the videotapes reinforced the idea that there was more visual communication occurring than an analysis based only on Drawing would indicate. It was necessary to expand the definition of what constituted visual communication.

Four additional modes of visual communication were identified and instances of each were noted and time stamped. Communicative Gesturing is analogous to Tang's first potential function that a gesture accomplishes, to express an idea [11]. An example would be a participant tracing her or his hand to show the path the device must travel along. Using Hardware is an instance of a participant using any convenient artifact to represent some component of the design they were working on. This particular use of hardware has been labeled by Brereton as "Hardware as a Communication Medium" [12]. Referencing Hardware is an instance where a participant verbally referenced an artifact that had a very distinctive geometry, a gear for example, to leverage other team members' visual mental representations of that artifact. Using Drawing is where a participant directly references a previously created sketch and builds off that visual picture to explain her or his idea. This five part definition of visual communication that emerged as analysis proceeded was much richer than the initial definition based solely in drawing creation.

It is readily apparent that these modes are not mutually exclusive from each other or from verbal communication. Some modes are more likely to be observed in conjunction with other modes of communication. In fact, there is current work to develop a theory of multimodal communication that recognizes combinations of speech, gestures, drawings and hardware usage occurring simultaneously [13].

RESULTS

Team Activity

The activity timelines of Team 1 and Team 4 are shown in Figure 4. Each box on the timeline represents the activity from Figure 3 that was observed on the videotape at each one-minute interval.

Two things that are striking about these timelines. First, the timelines show only moderate transitioning between activities for both teams. According to Atman, more transitions represent a more sophisticated problem solving strategy and a higher quality of approach to the problem. [10]

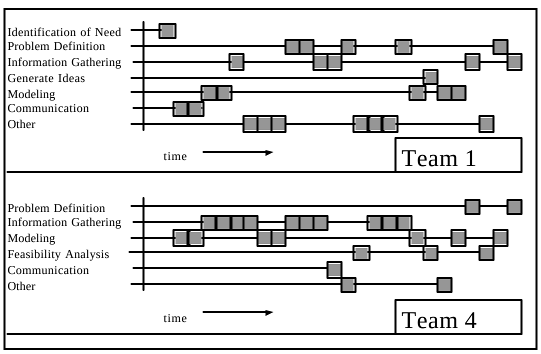

Figure 4. Team Activity Timelines

Second, it was anticipated that since the first segment of the exercise was framed as a conceptual design exercise, the teams would engage primarily in Identification of Need, Problem Definition, Information Gathering, and Generate Ideas activities. The video record shows that Team 1, the strongly visual team, spent most of the time engaged in Problem Definition, Modeling, and Information Gathering. The weakly visual team spent most of its time in Information Gathering and Modeling. Neither of the teams spent a lot of time in the Generation of Ideas. A reading of the transcripts shows that the first idea generated by both teams was selected to work on. The rest of the time was spent in gathering information about that idea and modeling it. This means that the teams operated minimally in the conceptual phase of design.

Where Visual Communication Occurred

Figure 5 shows the mapping between the different modes of visual communication and the varying activities for Teams 1 and 4. Activities primarily expected during the conceptual phase of design have a gray background.

Team 1	Drawing	Using Drawing	Gesturing	Using Hardware	Referencing Hardware
Problem Definition	2		21		
Information Gathering		12	8		27
Generate Ideas					3
Modeling	26	18	103		37
Communication		13	3		
Other			1		

Team 4	Drawing	Using Drawing	Gesturing	Using Hardware	Referencing Hardware
Problem Definition			4		
Information Gathering			28		10
Modeling			88		
Feasibility Analysis	35		11	200	
Communication			15		6
Other			1		

Figure 5. Visual Communication by Activity (in seconds)

The visual communication mode used most consistently was communicative gesturing, which occurred throughout most of the activities. For the strongly visual team, Team 1, most visual communication occurred during Modeling activity. Team 4, the weakly visual team, used visual communication primarily in the Feasibility Analysis and Modeling activities. Therefore the majority of visual communication was occurring outside of the conceptual phase of design.

How Much Visual Communication Occurred

The plots of the team communication patterns in Figure 6 highlight the amount of visual communication (in terms of percentage of total analyzed time) that occurred for each team.

There are a number of interesting things to note in these two plots. The first is the percentage of total communication that was visual communication; 18.4% for Team 1 and 32.8% for Team 4. The percentages for Teams 2 & 3 are 11.7% and 21.5% respectively (because of the lack of audio with the Team 2 & 3 tapes, there is more inaccuracy in their percentages). Even if these different communication modes were mutually exclusive, which they are not, the total amount of visual communication would still be a third of the total communication at best (Team 4). It is anticipated that a higher amount of visual communication would result in more effective communication, based on the preferences for the reception of information.

Team 1, which had the highest average preference for the visual presentation of information, had the next to lowest total amount of visual communication occurring. Team 4, which had a mild preference for the presentation of visual information had the largest amount of visual communication occurring.

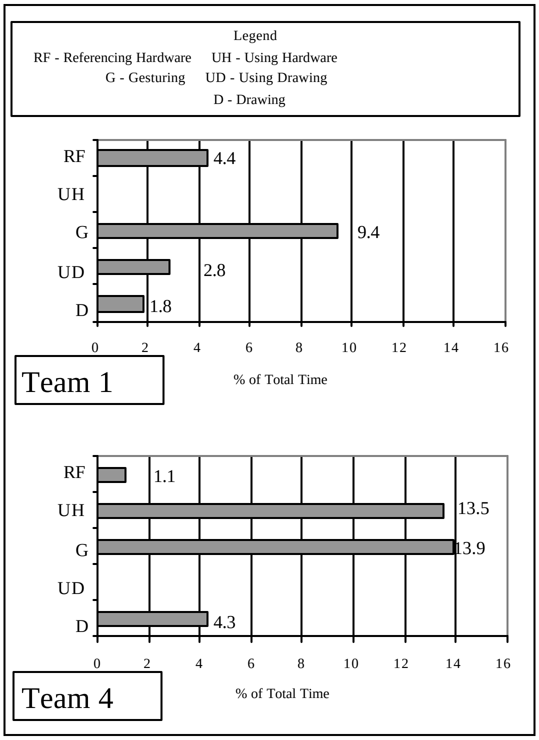

Figure 6. Visual Communication by Team

The last interesting observation involves the using drawing mode of communication. While both Team 1 and Team 4 engaged in drawing, only Team 1 used those drawings after they had been created.

Who Communicated Visually

The next two figures seek to connect the individual preferences of the participants for the reception of information visually with their actual visual communication. Figure 7 shows the individual communication patterns for Team 1, the strongly visual team.

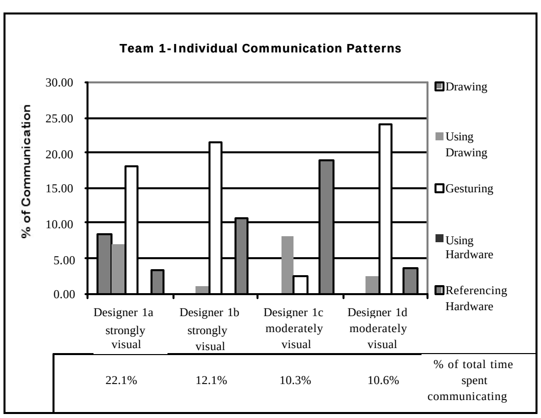

Figure 7. Team 1 - Individual Communication Patterns (numbers based on time)

The number at the bottom identifies the total percentage of time each participant was communicating. These do not add up to 100%. The remainder of the time either no communication was occurring or the communication of the participants was not germane to the design exercise. The bar chart at the top of the figure breaks down the visual communication of each individual based on total time spent communicating.

No patterns emerge from the comparison of the actual communication patterns with the preferences for the reception of information. Communicative gesturing was the most used mode of visual communication for all of the participants except Designer 1c. The only participant who drew, Designer 1a, was also the participant who communicated the most, almost double that of each of his or her fellow team members.

Figure 8 shows the individual communication patterns for the weakly visual team, Team 4. Three of the four participants on this team used hardware to communicate visually the majority of the time. Designer 4c particularly favored this mode of visual communication. The individual who engaged in participation the most, more than a third of the total participation, was the only team member to draw. As mentioned previously none of the other participants used those drawings to communicate visually. As in Team 1, no patterns emerge from the comparison between preference and visual communication.

There are a couple of differences between the individual communication patterns shown in Figure 7 and Figure 8. None of the participants in Team 1 used hardware to communicate while all of the participants in Team 4 used this mode of visual communication. Communicative gesturing, which was the primary mode of communication in Team 1, was the second highest preferred mode of communication in Team 4.

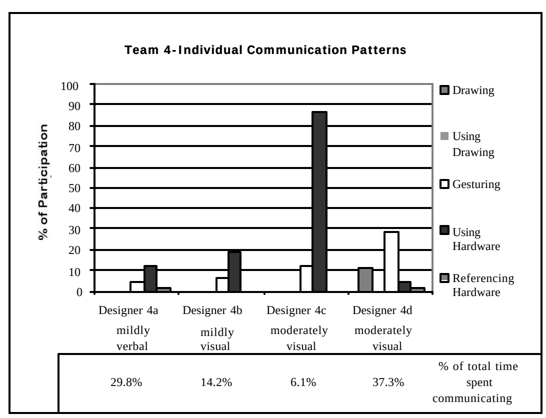

Figure 8. Team 4 - Individual Communication Patterns (numbers based on time)

CONCLUSIONS

Considerations for Experimental Design

The fact that the activity patterns of the two teams were quite different from what was expected may be due to the experimental design. The entire exercise was scheduled to last two hours, of which the first thirty minutes was intended to be the conceptual design phase portion of the exercise.. The amount of time remaining was of considerable concern to the participants and references to it occurred throughout the transcripts. The requirement to have functioning hardware at the end of two hours may have contributed to the participants selecting and modeling the first proposed solution. A possible consideration for future experiments is to provide the participants with as much time as necessary and/or frame the entire exercise around conceptual design.

Expanded Definition of Visual Communication

There did not appear to be a direct relationship between individuals' preferences for receiving information and their preferences for the presentation of information. However, the Learning Style inventory does serve the purpose of identifying the needs of individuals.

The initial assumption that visual communication is drawing was not borne out by the data. A much richer picture of visual communication was obtained by expanding the definition to include using drawings, communicative gesturing, referencing hardware, and using hardware. Although the majority of communication was verbal, and therefore mismatched with the preferences of the individuals, visual communication was occurring. Therefore, the needs of the individuals for visual information may have been met at a higher level than initially thought.

Future Work

These results suggest possible directions for further studies. The different modes of visual communication identified in this study do not seem to have equivalent effectiveness. For example, communicative gestures are irrelevant if the intended audience does not recognize them as an attempt at communication. The effectiveness of each of these modes is one possible question to address.

Another interesting question is whether an individual's communication patterns change following instruction. Short training sessions in the use of different modes of visual communication can be developed. Individuals will participate in equivalent design exercises before and after these training sessions and the communication patterns compared to determine the effect of the instruction.

A final question to be addressed is what outcome more effective communication has on the design process and final product. A quality measure for process and product will have to be adopted to judge whether communication that matches the presentation of information with preferences for receiving information truly improves design.

ACKNOWLEDGEMENTS

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