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A Study of the Use of Drawings to Explain Technical Information Among Young Adults

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Abstract. Do young adults choose to use drawings and sketches when attempting to explain technical information if not specifically prompted to do so? Engineers and technicians frequently use technical drawings and sketches to communicate. Is this a learned behavior or do people choose this form of communication without specific instruction to do so? Does completion of a graphics or drafting course improve the quality of sketches drawn while explaining technical information when the subject produces the sketches in a non-class environment without prompting to adhere to accepted graphics/drafting standards? The quasi-experimental study reported here sought answers to these questions.

Key Words: Technical drawings, sketches, engineering graphics education, problem-solving, technology education, technical communication

MSC: 51N05

1. Background

Sketches or diagrams used in problem-solving and/or design applications can serve multiple purposes. Written text tends to be sequential in nature, while diagrams and sketches are more holistic and even serve as a short-term memory aid. They have the potential to represent a large amount of information in a relatively small area. In addition to representing single objects, diagrams can also be used to represent relationships between objects (Novak [6], 1995). Larkin & Simon [5] (1987) discuss the use of diagrams to preserve the topological and geometric relations among the components of the problem. They give the following reasons why diagrams or sketches can be superior to written or verbal descriptions of a problem:

- Diagrams can group together all information that is used together, thus avoiding large amounts of search for the elements needed to make a problem-solving inference.

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- Diagrams typically use location to group information about a single element, avoiding the need to match symbolic labels.
- Diagrams automatically support a large number of perceptual inferences, which are extremely easy for humans [5, p. 98].

Larkin & Simon continue to explain that "diagrams can be better representations not because they contain more information, but because the indexing of this information can support extremely useful and efficient computational processes." [5, p. 98]

Even when students use diagrams or sketches, the number of sketches does not necessarily correlate with quality of design. Yang [10] (2003) conducted a study with twenty-four upper-level engineering students in a 10 week project-based design course. The students designed and built an electro-magnetic robot device for a "capture the flag" contest. The source of data was paper-based design logbooks kept over the 10 weeks. The logbooks included written descriptions of their work, detailed process plans for fabrication, equations, and sketches. Drawings in the logbooks were counted and indexed by date and type. Sketch quality was not considered. Only the quantity was considered. Sketches were categorized as sketch or a dimensioned sketch. The number of dimensioned drawings during the first 3 weeks of the design cycle correlated significantly with students' final grades. The number of dimensioned sketches created in week 7 of the course correlated significantly with students' contest performance. Yang [10] concluded that the total sketching volume did not correlate with the graded design outcome. In other words, a student could create a large number of sketches that served no purpose in the design process. In addition, an experienced designer could create a small number of high quality sketches that significantly served the design process.

Part of the problem with student created diagrams or sketches is the lack of quality. Most students do not get focused practice sketching free-body diagrams, pictorials, or motion diagrams before enrolling in physics, mathematics, or technology education courses. When solving problems, students tend to focus more on the formulas and desired answer than constructing free-body diagrams or pictorial representations of the problem (Van Heuvelen [9], 1991).

In addition to being a tool for problem-solving, carefully designed sketching activities have also been shown to be one of the best activities for developing spatial visualization skills (Sorby [7, 8], 1999, 2000). Engineering graphics educators continue to include sketching activities as an integral part of the curricula to enhance students' spatial skills and improve their ability to communicate designs effectively (Barr [1], 1999; Branoff, Hartman, & Wiebe [2], 2002; Demel, Meyers, & Harper [3], 2004).

2. Methods

Young adults from upper level high school mathematics classes and introductory university classes were solicited to participate in a voluntary activity. Of the 101 participants, 50 were in high school and 51 were university students. Consent to participate was acknowledged by all subjects and then the directions for participation were given. Verbal instructions were limited to a brief introductory statement by the proctor which was read from a script. The key statement was:

> "We are asking you to participate in a study to assess the ability of students to communicate technical information. You will be given a one-sheet instrument. On one side it reads:" (hold instrument up to show)

> "Use only this sheet of paper and the pencil to instruct a sighted, literate, but uninformed adult on the topic:"
>
> **"How an Airplane Flies"**
>
> "We realize that there will be various levels of knowledge about the topic chosen. Some of you might not know much about it while others are experts – but we ask you to do the best you can on this. There is no specific time limit, but most of you will only need 5 to 10 minutes."

Participants were also asked to provide demographic information requested on the reverse side of the form, but to do so only after they had completed their response on the front side. This was done to prevent them from seeing questions about experience in drafting/graphics courses and hence being inadvertently prompted to draw in their responses. The directions concluded by thanking participants for their effort and informing them where to place their completed forms.

Participants who asked questions concerning how to respond or if a drawing was required were simply told that the proctor could not answer any questions. Each participant was then given the instrument form (front side up) and a pencil. There were no lines or graph paper grids in the blank area designated for responses. The researchers felt that lines might prompt respondents to limit their responses to written answers while graph grids might cue them to include sketches or drawings – it was desired to have subjects respond in the way that they would choose with no prompting.

Data were collected in classroom settings in which students had ample desk surface to write or sketch and separation space appropriate for classroom test-taking. There was sufficient light, ventilation, freedom from interruption, and a quiet atmosphere was maintained throughout the administration period. Following participation subjects were told that one of the key research questions in the study concerned whether or not people voluntarily chose to use drawings or sketches in their responses.

The demographic data collected included: Age, gender, class/grade, major (for college students only), technical and drawing or related courses taken, and hobbies concerning flight. The intent of the researchers was to use these demographic factors in sub-analyses and comparisons to see if there were differences in the quantity or quality of sketches included with participants' explanations.

Following guidelines for increasing the objectivity of rating of written essay test responses by Haynie [4] a model response was developed to serve as a key for the raters to use in scoring the responses. A rating instrument was developed and duplicated such that each of the three researchers could independently rate each participant's response. A pilot study of 12 sample cases was conducted early in the development process to revise instrumentation and procedures. In the actual study, all participant response forms were assigned a code number which was placed on both sides of the form by an uninterested administrative assistant. Raters only viewed the front (response) side of the forms while completing the rating forms, so they knew nothing about the demographics of the particular respondent being rated. On the rating forms, raters identified themselves first and then the participant via code number only. Some of the ratings simply involved counting the quantity of some element (such as number of words in explanation) and entering a number. Others involved entering a rating value using the following scale:

0 = None (F), 1 = Poor (D), 2 = Average (C), 3 = Good (B), and 4 = Outstanding (A)

according to the individual rater's best judgment. The following categories were evaluated:

Number of words in written response

Number of drawings used

Number of technical (jargon) words used (scientific, mathematical, technical)

Technical accuracy of concepts in drawings

Accuracy of drawings in terms of "standard" presentation expectations

Accuracy of concepts in the text

Written expression (use of standard English)

Overall effectiveness of communication

Did you (the rater) feel that the person knew the concepts?

Once the three raters had independently assessed all of the participants' responses, the administrative assistant entered all of the data into a simple text file for analysis. To insure that the data file was accurate, the rating forms were sorted to align them properly with the participants' response forms. The first step in the analysis averaged the independent ratings of the three raters to yield a single value for each participant in each rated category.

The three raters were experienced drafting and graphics teachers (20–36 years) and each had ample knowledge of the concepts of flight. To insure that the raters accurately understood the instrumentation and to provide an informal degree of inter-rater reliability, a small pilot study was conducted in which 12 sample response forms (collected from students in one of the researcher's classes but not a part of the study) were independently rated and then the ratings were discussed to seek further agreement. Agreement was nearly perfect with only a few ratings varying at all and none by more than a single point — there were no major disagreements. One issue that was discussed was whether or not to count words used as labels in sketches as part of the total word count for the written response. It was decided that these were part of the drawings and not part of the verbal explanation. The researchers decided to proceed with rating the forms independently feeling comfortable that each adequately understood the instrumentation and there was common understanding of the rating system.

Appendix A includes both sides of the completed response instrument from one student (Case # 64) and one of the three rater's assessment instrument for that student's entry. These will help the reader to interpret the findings presented in tables and text that follow.

3. Findings

The demographic data are reported in Table 1. Half of the respondents were high school students and half were college students. Among the college students, 62% were not studying in technical majors. Two thirds of the students were male. Half of the students had experienced at least one drafting or graphics course.

The grand means for all of the rated and tabulated values appear in Table 2. The range and standard deviations are also given for the rated categories. Each mean represents the average of all three individual rater's scoring of the 101 participant response forms for a given rating category. The average number of words used in explanation of the concepts was about 66 words, but one participant only used two words and one used 177. Though at least one respondent used 3 separate drawings in the response, many used none and the average was less than a half drawing per respondent. As can be inferred by the large standard deviation, many students actually used no drawings and some used 2 or 3. A different analysis found that 40

Table 1: Demographic data

Categories	N	%
Level:		
high school	50	49.5
college	51	50.5
Gender:		
male	67	66.34
female	34	33.6
Major: (college students only, $n = 51$)		
technical	19	37.25
non-technical	32	62.75
Technology education courses:		
yes	63	62.38
no	38	37.62
Drafting or graphics courses:		
yes	51	50.5
no	50	49.5
Art courses:		
yes	34	33.66
no	67	66.34

N = 101

Table 2: Grand means of all ratings

rating category	mean	SD	minimum	maximum
number of words	65.98	39.58	2	177
number of drawings	0.495	0.712	0	3
technical jargon words	1.165	1.426	0	7.67
technical accuracy of drawings	0.713	1.033	0	3.33
accuracy of form of drawings	0.722	1.03	0	3
accuracy of concepts in text	1.459	0.914	0	3.67
written expression (stand. Eng.)	2.052	0.651	0	3.67
overall effectiveness of commun.	1.647	0.724	0.33	3.67
knowledge of concepts apparent	1.396	1.042	0	3.67

N = 101

of the 101 participants used at least one drawing while 61 (60.4%) attempted to explain these technical concepts via written words alone with no sketches or drawings whatever.

The next step in the analysis was to compare means of selected groups to determine whether demographic factors were related in any way to a student's disposition towards using drawings or their skill in doing so. All of the factors reported in Table 1 were used as basis for these sub analyses. Though one might assume that there would be many potential relationships within this large group of contrasts, only one factor was found to have any bearing on the use of drawings in explaining the concepts by these students. Table 3 provides findings concerning students who have taken or who have not taken a drafting or graphics course (either high school or college level). This factor had nearly equal numbers of participants in its two groups (51 with a drafting course and 50 without). The grand mean of the number of drawings employed was 0.495 and 61 students had not used any drawings at all. So, the question was, of those students who have taken a drafting or graphics course, what percentage choose to use drawings or sketches in explaining technical concepts when not specifically prompted to do so? And the follow-up question was, what is the quality of the drawings that they use compared to students without the experience of drafting courses?

As shown in Table 3, students who had experienced a drafting or graphics course appeared to be more likely to include at least one drawing in their explanation of the technical concepts they were explaining in this experiment than those students without such a course (45% VS 34%), but the Chi-Square finding on this result was non-significant. However, the quality of the drawings produced by students with a drafting or graphics course was better in technical accuracy of form (adherence to technical graphics standards). This was demonstrated by comparing the two means with the GLM Procedure in SAS (Statistical Analysis System) with the significant result: $F(1, 199) = 7.85$, $p < 0.0061$. However, it must be noted that even the mean of the group who had experienced drafting classes was quite low. Their mean was 1.0 which indicates that the drawings were evaluated as "poor" by the raters.

Table 3: Drafting course takers vs non course takers

category / rating	**graphics course**	**no graphics course**
number of students who used drawings	23 (45.1%)	17 (34%)
number of students with no drawings	28 (54.9%)	33 (66%)
Chi-Square results:		
$X^2 = 1.30$, DF = 1, $p = 0.254$, NS		
means examined –	**mean (SD)**	**mean (SD)**
	Yes	**No**
drawing quality ratings of drawings	1.00 (1.21)	0.44 (0.74)

GLM F test results –					
source	DF	sum Sq	mean Sq	F value	Pr > F
model	1	7.9176	7.9176	7.85	0.0061*
error	99	99.8756	1.0088		
corrected total	100	107.7932			

* = significant difference at $p < .05$, NS = non significant

It is possible that the participants who had experienced the drafting courses also had greater technical knowledge of the subject than did the non-drafting students and they may therefore have also had some advantage in performing this particular task. Still, the overall effectiveness of communication was better for the students who had taken a drafting or graphics course and part of that advantage surely is a result of inclusion of drawings in the explanations.

4. Discussion

Three straightforward research questions were addressed by this study. In general they asked if young adults use drawings to explain technical concepts, if taking drafting/graphics courses influences their use of drawings, and whether such courses improve the quality of the drawings they use. The findings concerning them were:

Do young adults choose to use drawings and sketches when attempting to explain technical information if not specifically prompted to do so?

Within the context of this study, 40% of upper high school and early college students were found to use drawings or sketches in explaining “how an airplane flies” while 60% attempted to answer the question with prose exclusively. Though one might expect students in technical majors to use drawings more frequently than non-technical students, no difference was found in the number of drawings by students in this study. Some of the drawings by non-technical students were more nearly “decorative pictures” rather than technical sketches, but they were drawings just the same. This factor should be examined more closely in follow-up studies. One wonders if persons who use graphics and sketches in their work (such as engineers, teachers of technical subjects, and tradespersons) would be more likely to use sketches to answer the same question. This question lays the groundwork for follow-up investigations.

Does completion of a graphics or drafting course predispose young adults to use drawings and sketches when attempting to explain technical information if not specifically prompted to do so?

Care was taken in this experiment not to prompt respondents to use either written prose or sketches, but to leave the selection of how to answer the question totally up to them. To this end, the response instrument had neither lines for writing nor graph grids for drawing but was simply blank save the heading with the question and a footer requesting completion of the demographic data on the reverse side. The proctors read instructions from a prepared script and answered no questions from participants. One would hope that, under these circumstances, students who had experienced a drafting or graphics course would have a disposition towards use of sketches and drawings in explaining any technical concepts in which they would be helpful. Though there was an apparent trend in this direction (45% of drafting students used drawings compared to only 34% of non drafting students), Chi-Square results showed it to be non-significant. This was a disappointing finding to the researchers.

Does completion of a graphics or drafting course improve the quality of sketches drawn while explaining technical information when the subject produces the sketches in a non-class environment without prompting to adhere to accepted graphics/drafting standards?

The responses were independently rated by three professionals with long term experience in teaching drafting and graphics courses. There was a significant finding that, when sketches were used in the participants' responses, those prepared by students who had experienced a drafting or graphics course were superior to those of the non-drafting students. So, graphics and drafting courses are minimally succeeding in improving the technical merit (form and adherence to standards) of sketches produced by their alumni.

Though the researchers were gratified by the answer to the third question, that drafting courses improve the quality of sketches by students, they were somewhat alarmed by two other findings: The low quality of the drawings even by the drafing class alumni and the finding in answer to the second question. Perhaps, had the instructions been differently worded to remind students to use accepted graphics standards in any drawings, or had the experiment been conducted in a technical graphics lab or drafting room, former graphics students would have inferred an expectation of formality and risen to the challenge of producing better drawings while non-graphics students would have performed no better than they did here for lack of knowledge. But the experiment sought typical rather than staged performance, and the typical performance of these participants did not evidence a high personal value on the standards of the graphic language outside of their drawing class.

Educationally, it should follow that among the objectives of any drafting or graphics course high quality of drawings produced would be important. But, as addressed by question 2, should not also an increased disposition toward employment of the visual communication channel be a key objective of all such courses? If it is, whether specifically stated or simply implied as an obvious goal, the findings of this experiment failed to support its attainment. Perhaps such courses need increased orientation information "up-front" or "debriefing" information at the end to better illustrate the main point of the course: That the visual communication channel via drawings and sketches is very important for communication of technical concepts. Possibly exercises within the courses should have students attempt to explain technical concepts with and without drawings or sketches to emphasize the value of graphic communication. What is the use of students taking graphics courses if those courses fail to inspire them to draw or sketch when they explain technical concepts? How valuable are the courses if their alumni do not value the standards taught to an extent that they become part of their "typical" behavior?

Further studies using the instrumentation of this study in different settings are in development. Perhaps further investigations should include professional engineers and other sorts of participants. Additionally, replications with different technical information and concepts as the question of concern are encouraged; it is acknowledged by the authors that the difficulty of this particular problem may have been frustrating for students who did not know the subject matter well. The overall mean for technical accuracy of concepts, 1.46 (Range = 0 3.67) reveals that students were significantly challenged by the topic. Follow-up investigations of similar design using less difficult subject matter are encouraged. Unless it can be demonstrated that drafting and graphics courses influence their alumni to choose the visual channel for communication when it is appropriate and to use the information that they learned to improve their sketches outside of class, the value of those courses remains in question.

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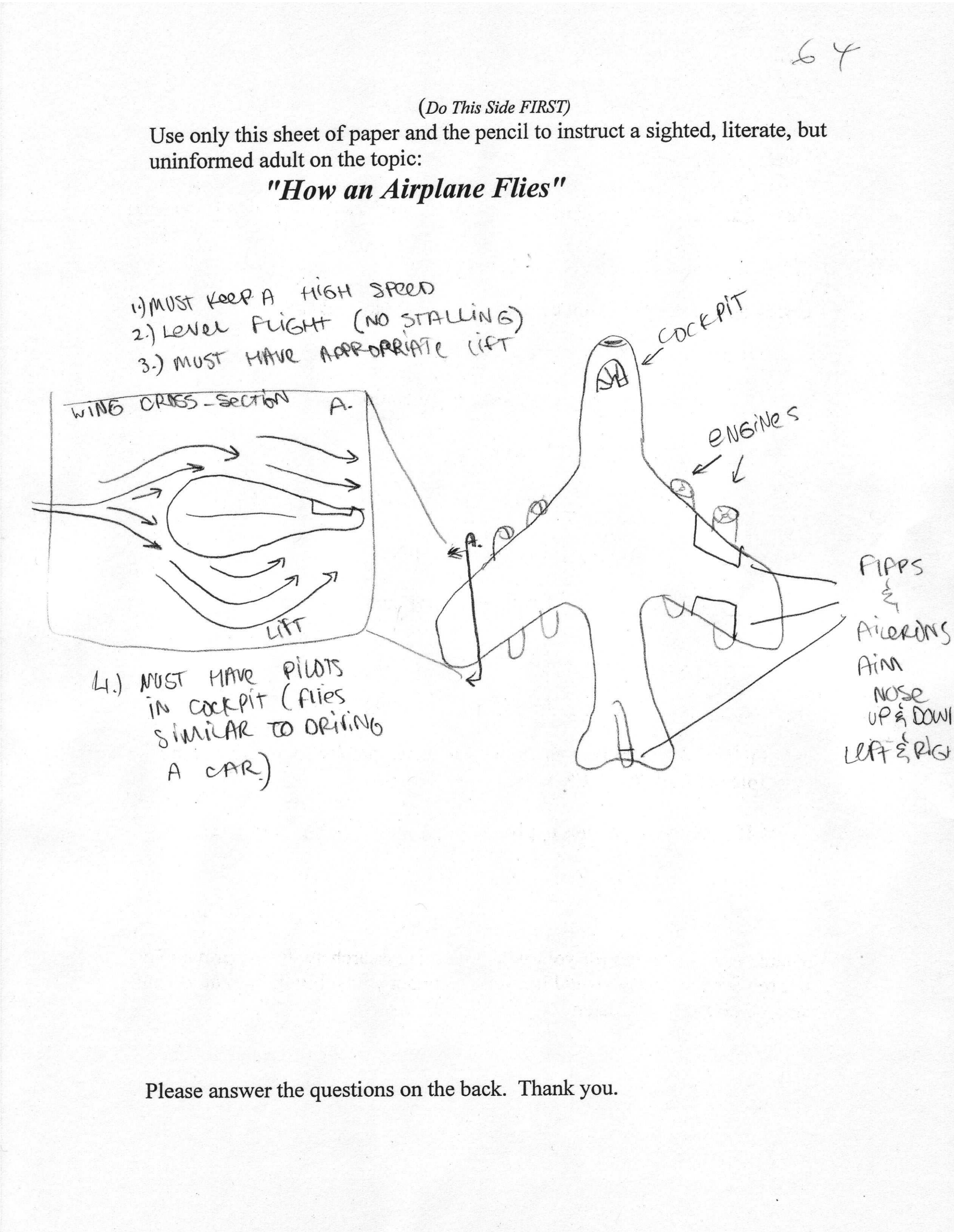
Appendix A

Both sides of the study instrument completed by subject # 64 and the rating instrument completed by rater # 2 are shown in the following images (pages 224–226).


64

(*Do This Side FIRST)*

Use only this sheet of paper and the pencil to instruct a sighted, literate, but uninformed adult on the topic:

"How an Airplane Flies"

1.) MUST KEEP A HIGH SPEED
2.) LEVEL FLIGHT (NO STALLING)
3.) MUST HAVE APPROPRIATE LIFT

4.) MUST HAVE PILOTS IN COCKPIT (flies SIMILAR TO DRIVING A CAR)

Please answer the questions on the back. Thank you.

Study instrument, subject # 64, first side

0064

(Do ***Other Side*** *First)*

Please tell us about yourself:

Age 23 Sex M Class/Grade: (circle) **Fr** **So** **Jr** **Sr** 16

Major TED/GC 02

Check any of the following courses which you have taken:

High School	College	
	X	Technology Education
	X	Engineering
		Aeronautics
		Technical Writing
X	X	Drafting or Graphics
		Art (drawing)
	X	Methods of Teaching

Do you have any hobbies that would influence your ability to explain the principles of flight? **YES** **NO** (circle your answer)

If Yes, what hobbies apply?

Thank you very much for your help with this research study. Your name is not required and no personal information about yourself will be shared with anyone else for any reason.

Study instrument, subject # 64, second side

Rating Sheet, Use of Graphics Experiment Form: 64 Rater: 2

Number of Words 38 Number of Drawings 2

Technical Jargon Words 4 (Scientific, Mathematical, Technical, other)

Technical Accuracy of Concepts in Drawings 2 (highest if multiples)

Accuracy of Drawings—standard presentation concerns 2

Accuracy of Concepts in Text 1

Written Expression (use of standard English) 2

Overall Effectiveness of Communication 1

Did you feel that the person knew the concepts? 2

Ratings:
0 = none (F), 1 = Poor (D), 2 = Average (C), 3 = Good (B) 4 = Outstanding (A)

Rating instrument, rater # 2

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