Through a Microscope, Darkly: Students' Perceptions of What Scientific Communication Is and What It Achieves

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Introduction

The substance of science is only as sturdy as the interlocking framework of human experience on which it is built. The value of any knowledge, scientific or otherwise, is determined by two components: the worth of an individual experience, and how connections are forged between experiences. Scientific communication as embodied in formal texts is similar to communication between non-experts in any other medium. Insofar as science is simply another form of human interaction, scientific communication is vulnerable to all the pressures, complexities, and difficulties found in daily communication.

The first challenge of describing scientific communication is to describe science. While the construct of "science" implies concepts like precision or extraordinary attention to detail, science as a professional activity defies simple classification. Ester M. van Djik has argued that fields within science share only a "family resemblance" to each other. While common traits exist, not every feature that may be considered scientific occurs within every scientific discipline (1088). For example, explanations of the scientific method usually provided to secondary school students cannot account for the fact that the Human Genome Project did not have a hypothesis, even though that undertaking was certainly scientific (1087). While convenient lists of aspects may be compiled to separate science from all else for practical purposes, the fundamental heterogeneity of science remains. If a wide diversity exists simply within the practices that may be considered scientific, it follows that communication by scientists takes on many forms and purposes.

Communication is critical to science. Theories of how and why we communicate information to each other about the physical world began to emerge by at least the classical age, and modern scholars have shown how concepts first produced by Aristotle may still be applicable to the physical sciences as they are practiced today (Wickman 22). Rhetoric becomes central to science when each scientist must bring back knowledge attained through research to a common level of understanding shared by their peers in order to legitimize themselves (24). However, the details of how knowledge should be transferred remain unclear to many who find themselves in a position to do so, as do the possible extended consequences that occur when knowledge spreads beyond the experts (Kayes and McPherson 1012; Schneider 192). A scientist gains his identity as a scientist partly through the way in which he communicates his work.

Critical to science are expressions of uncertainty (Kritzer 47; Hyland 433; Schneider 193). Ken Hyland analyzed the instances of qualifications of claims made in molecular biology articles and argued that many instances were associated with “diplomatic considerations” rather than direct attempts to arrive at an objective truth (434). Diplomatic considerations are necessary because, in science, “the writer is dependent on the ratification of the reader” (Hyland 436). Expressing tentativeness in results sometimes provides a mean for scientists to express their personal feelings on a subject, or armor themselves against refutation (Hyland 435). While these expressions of uncertainty often perplex non-scientists about the potential impact of a scientific finding, scientists who do not make qualifications about their findings often compromise their perceived authority as scientists (Kritzer 44; Schneider 192). In order to benefit from the general esteem the public holds scientists in, the individual must communicate in a manner consistent with his profession.

The identity of the author influences what is written as much as the topic. The author’s relationship with his or her editors and audience plays a critical role in publication, and hence the advancement of a scientist’s career (Lipworth and Kerridge 99). Even the comments produced in review of an article can be considered part of scientific communication, and the reviewer an author with individual motivations. While power may be assumed to radiate from reviewers and editors, in actuality the power dynamic depends on the identity of individuals, not their titles or formal roles in the review process (99). For example, a reviewer of a senior scientist’s article may expedite the review process by offering praise or minimal suggestions for revision. Every possible relationship between the individuals implies a different style of communication, creating a situation parallel to everyday interactions.

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The scientific community expects other standards from research, even if those standards do not always raise the quality of research in terms of applicability to problem solving. Reviewers prefer measurements that have a minimum reliance on subjective factors, even when “objective” measurements are less reliable in a particular study (Kayes and McPherson 1013). Kayes and McPherson expressed their frustration in research done in clinical settings that must use sophisticated yet inaccurate methods to acquire indications of the stages of a patient’s recovery when “subjective” interviews are more relevant (1012). Researchers often feel pressured by the situation that exists in scientific communication to create a veneer of objectivity in their papers simply to disseminate their research (Kayes and McPherson 1012). In the sense that the quality of objectivity is being highlighted only to convince an audience, certain practices of scientific inquiry are purely rhetorical at least some of the time.

Scientists must also be “diplomatic” in the way they frame an argument itself. While science is known for its ability to grow through rejection of flawed theories, scientists must be cautious not to be openly confrontational to a theory that is deeply entrenched (Hergovich, Schott, and Burger 190; Armstrong and Hubbard 137). The peer review process, which is the most common path research takes to dissemination within the scientific community, may serve as both a protection against fabrication and a roadblock to innovation (Armstrong and Hubbard 137). Criticism in a review often serves to propagate a judgment arrived at before the article in question was even written (Hergovich, Schott, and Burger 198). While there exists broad consensus that censorship of controversial findings is counterproductive over long periods of time, relatively few controversial papers are submitted for publication, implying that scientists are cognizant of the risk tied to being controversial when selecting research topics or crafting their papers (Armstrong and Hubbard 137). Feedback provided on a paper with findings that do not support opinions held by its reviewer is far more likely to be negative, even on the aspects of the paper that are not controversial (Hergovich, Schott, and Burger 198). Criticism that is written in argument against a viewpoint is rhetorical when that criticism is not consistent with evaluations of viewpoints the reviewer finds agreeable. In order to avoid undesirable criticism and attacks on their competence, researchers must have skill in writing for an audience.

While scientific communication is parallel to normal conversation in that it is often persuasion-oriented, important differences exist between the two. In contrast to the extreme partisanship that exists in common life, the conclusion of research is not necessarily "for" some party or "against" another (Kritzer 47). Science seeks to diminish falsehood, while everyday debates seek to claim some definitive truth (Kritzer 47; van Djik 1090). Scientific communication typically seeks to persuade an audience, but it is inaccurate to characterize the scientific process as being grossly dominated by social positioning or monetary incentives, especially when viewed in contrast to the courtroom (Kritzer 47). Many aspects of science do not have parallels in everyday life, and therefore some conversation modes in science are indeed unique to it.

When science becomes entangled in debates involving the general public, nuances must be simplified and information condensed. In the case of political debates, science is often simplified to the point of being rhetorical, and it may suffer as its use to persuade the public is antithetical to the public's perception of science as impartial (Kritzer 45; van Djik 1092). This situation has happened recently to climate science (Biello). Some of the blame over failures to effectively communicate information to the public rests with scientists (Schneider 184). Public opinion has an impact on what research ultimately gets conducted. For a scientist to continue his research it may be necessary to effectively communicate with non-experts (Edmondston, Dawson and Schibeci 2453).

The ability of a scientist to respond to the pressures imposed on scientific writing is first dependent on her familiarity with the fundamental existence of those pressures.

Presenting research is a complex task that far exceeds the listing of facts. Despite the complexity of the task, undergraduate students with science majors often list their ability to communicate as one of the least important of the skills they need to acquire, while most active scientists view communication as being crucial (Edmondston, Dawson and Schibeci 2462). However, active scientists do not always use this communication for its intended purposes, instead allowing personal motives to take over (Armstrong and Hubbard 137). If change is to be made in the conduct of science, the optimal time to start molding future scientists is before or during their first years of graduate level education (Institute of Medicine and National Research Council of the National Academies 26). It is hoped that, given time to reflect, undergraduates' opinions about priorities in their education can shift to being more receptive to skills not strictly associated with their major (Edmondston, Dawson and Schibeci 2461).

The ability of a scientist to respond to the pressures imposed on scientific writing is first dependent on her familiarity with the fundamental existence of those pressures. Ester van Djik sees among the public "a widespread naïve view…that science is objective and value free" (1092). Do students share this "naïve view?" What role do science and engineering majors see the form and function of communication playing in their future work? In order to train prospective scientists in communication relevant to their field, a baseline reading of attitudes on the subjective elements in science is needed. This research was designed to discover that baseline among a random sample of students at the University of Central Florida.

Methods

How do students understand the dimension of science created by communication? Does a rift exist between science/engineering students and non-science students over the place of communication? The investigator designed a survey to address some of the questions raised indirectly by previous authors on the subject of scientific communication, as well as to test a number of their claims. Based on the literature, the investigator expected to find that students are not generally aware of communication in science, yet acknowledge that there can be some human influence on empirical research. Differing views on the role of communication are also expected to exist between science/engineering students and general students.

UCF students took the survey, completing it in approximately seven minutes depending on how thoroughly they answered. Surveys were filled out by student participants in the presence of the investigator, who provided clarification when necessary but otherwise did not seek to interact once the survey was underway. The investigator offered an explanation of research to every survey taker before the survey began, and offered a small reward for participation when available.

The survey consisted of eleven questions, four of which had multiple parts. It had six dichotomous questions, five questions rated on a ten-point scale, three free-response text boxes, two numerical response boxes, and one question that asked science or engineering students to identify their major. For demographic purposes participants identified as either science/engineering students or other, chose between male and female, reported the number of years of college they had completed, and indicated whether or not they had satisfied their English/Communication degree requirement. The survey used number of years in college in place of proximity to graduation to reflect the fact that many students may have more college experience than freshman/sophomore/junior/senior categories can accurately reflect. Determining years in college gives a better indication of how much opportunity a participant has had to move away from the simplistic view of science taught in secondary school.

Including sub-parts of multi-part questions, the survey asked two questions concerning definitions in scientific communication, six questions on how subjectivity could alter science, and two questions on scientific communication as practiced by the participant. Thus, the main focus of the survey was the interaction of human elements and ideals in science.

The investigator had previous contact with less than a sixth of participants, and did not know any of the participants personally. While a small reward was offered for participation, in most cases it did not seem to be a major influence on participants' willingness to take the survey. While a table in a public space on campus was initially utilized, it was found that immobility hindered the collection of data. The investigator instead walked to locations where science and engineering students were likely to congregate, such as the UCF Math and Physics building.

The investigator created a database to house the survey responses, and much of the data analysis was done using custom-written scripts. One method the investigator used to sort responses was to take an average of the character count of the final free-response question for all participants, then to sort between those who had written more than average and those who had written less. The length of time spent on a response indicates attention to the survey, and perhaps also indicates traits that other survey takers do not possess. In its electronic format the investigator was able to search the text of the responses for recurring words or phrases.

This survey was difficult to take in comparison to other surveys, as many of the questions asked the survey taker to generate opinions on topics they may have been only vaguely aware existed. Yet the possible obscurity of the topic to survey takers when contrasted with its large actual importance to their future lives made the possible difficulty fitting. While the survey used no language that can be even remotely considered technical, some of the language could admittedly have multiple and slightly divergent meanings to individual survey takers (see Appendix A for the text of the survey). To explain exactly what was intended by every term in every question would have unduly guided participants towards the survey writer's own conclusions. The investigator could not resist giving hints of his opinion when asked for examples or clarification by a significant minority of participants. As ambiguity is part of the topic of scientific communication, it was informative to simply infer participants' understanding of terms from their responses. In fact, the interpretation of misguided responses proved to be a tool used in analysis.

"Science major," "STEM (Science, Technology, Engineering, and Mathematics) major," and occasionally "scientist" will be used interchangeably to conveniently identify participants or groups of participants within the College of Science or College of Engineering and Computer Science. Another convenience used here is the frequent omission of the word "average" when referring to numbers that represent entire groups.

Results

Fifty-two students participated in the survey. Half (twenty-six) had majors in either the College of Science or the College of Engineering and Computer Science at UCF. Half were male and half were female, although students with science or engineering majors took up a larger proportion of the male students than female students. Participants had completed an average of 2.63 years of college. STEM majors had negligibly more college than non-STEM majors (2.65 verses 2.62 years). The twelve female science majors were less experienced than the fourteen male science majors (2.08 verses 3.14 years). Demographic information is summarized in Table 1.

	All Science Majors	**Male Science Majors**	**Female Science Majors**	**Non-Science Majors**	**Low Response**	**High Response**	**All Data**
Number in Group	26	14	12	26	32	20	52
Average Years of College	2.65	3.14	2.08	2.62	2.59	2.70	2.63
Ratio of Male to Female	14/12	14/0	0/12	12/14	13/19	13/7	26/26
Number who have Completed Communication Requirements	19	12	7	21	22	18	40

TABLE 1 Demographic Information Note: "Science" and "Non-Science" refer to the participant's major. The categories "Low" and "High" response are based on the average word-count on question eleven; those rated "High Response" wrote more than average on that question.

Table 2 summarizes averages for rating scale questions. The first column contextualizes the average. In general, a higher rating number meant "very much" and a lower rating number meant "very little". Table 3 summarizes percentages in Yes/No questions. Table 4 presents question nine responses. The same information can be found in greater detail in Appendix A.

	All Science Majors	Male Science Majors	Female Science Majors	Non-Science Majors	Low Response	High Response	All Data
4b) Current knowledge	4.95	4.42	5.86	5.85	5.18	5.71	5.41
5). Science Subjectivity 1	6.50	6.29	6.75	6.69	6.41	6.9	6.60
6). Science Subjectivity 2	4.42	3.86	5.08	5.31	4.97	4.70	4.87
8). Comparability to everyday life	5.88	6.00	5.75	5.19	5.75	5.20	5.54
10). Value built in by presentation	6.40	5.92	6.92	7.48	7.07	6.75	6.94

TABLE 2 Rating Scale Averages Note: only those who indicated completion of their communication requirement answered 4b.

	All Science Majors	Male Science Majors	Female Science Majors	Non-Science Majors	Low Response	High Response	All Data
4) English Completion	73/27	86/14	58/42	81/19	69/31	90/10	77/23
7). Is simplification ineffective?	33/67	50/50	17/83	19/81	25/75	30/70	27/73
7c). Can simplification be dishonest?	52/48	46/54	58/42	46/54	41/59	60/40	49/51
9). Will you do research?	73/27	93/7	50/50	46/54	53/47	70/30	60/40

TABLE 3 Percentage of Yes/No Responses Note: Percentages are based on the number in each group.

	All Science Majors	Male Science Majors	Female Science Majors	Non-Science Majors	Low Response	High Response	All Data
9). Percent of effort spent on presentation?	44	43	46	53	53	41	48

TABLE 4 Expected Percent of Research Effort Spent on Presentation

The accumulated data of all fifty-two participants was fascinatingly average. For example, when asked whether simplification ever amounted to dishonesty, twenty-five responded “Yes” and twenty-six responded “No” (one participant neglected to answer). Few of the rating scale question averages were below four or above seven.

Students were roughly equally divided on whether or not simplification ever amounted to dishonesty. Female scientists were the least trustful of simplification, while male scientists shared the views of the non-science group. Male science majors saw the least room for subjectivity in science, while female science majors and non-science majors saw the most.

One quarter of all survey takers believed that simplification could never effectively convey information. Male and female STEM majors disagreed most on this point; fully half of male STEM majors indicated that simplification can never work, while eighty-three percent of female STEM majors indicated the opposite.

Sixty percent of all survey takers expected to do research or develop new technologies in their future. Those survey takers who expected to do research expected to spend forty-eight percent of work done on a project on aspects related to the presentation of that project. Female science majors expected to spend three percent more of their effort on presentations (forty-six versus forty-three percent of effort), although only half of female science majors expected to do research, as opposed to ninety-two percent of male science majors. Female science majors and non-science majors had the smallest proportions planning to do research.

All groups indicated slightly positively that scientific communication can be considered analogous to everyday communication. Male scientists saw the greatest equivalence between daily and professional communication, while non-scientists saw the least. This difference, however, was slight. Even though science majors were slightly more hesitant than non-science majors in acknowledging a role for communication in changing science, they drew more parallels between science and everyday communication.

The categories "Low Response" and "High Response" are inclusive of survey takers from all categories. Roughly sixty percent of survey takers fall into the "Low Response" category, while the rest are "High" responders. These categories were created by averaging the character count on the last question, then dividing participants into those who wrote more or less than that average. The average character count was around one hundred sixty characters, or slightly more than a "tweet."

A significant number of free responses proved to be thoughtful, and, as they serve as a direct window into students' thoughts, the full text of every free response has been reproduced in Appendix B. While Appendix A contains data tables of sub-categories parsed on number of years of college, the sample size in each category was too small to approach relevance.

Discussion

The survey provides some indication that science majors prioritize communication slightly less than non-science majors. Even though science majors had completed more college on average than non-science majors, a smaller proportion of science majors had completed their communication requirement.

The amount that a respondent wrote can be used to infer several points. Firstly, ninety percent of high responders had completed their communication requirement, versus roughly seventy percent for the low responders. The case may be that completion of the communication requirement actually boosts students' abilities to respond in writing. Secondly, those who wrote the most were the most likely to believe that simplification could be dishonest. Their willingness to write at length for this survey might therefore be seen as an attempt to be completely honest. Whether students had completed their communication requirement or not was the biggest predictor of their response for the possibility for dishonesty in simplification. Third, those who wrote more than average were more likely to indicate that they planned on doing research. This suggests that the average researcher is actually a person who enjoys or feels an obligation to communicate.

Roughly half of all respondents agreed that simplification could amount to dishonesty. Simplification is a tool of communication. If the investigator was asked to clarify what the question about simplification and dishonesty meant, he often observed that participants were trying to distinguish between intentional dishonesty on the part of a researcher and accidental dishonesty as a result of simplifying. That science majors and non-science majors were both roughly equally divided on whether simplification can be dishonest is surprising, as what constitutes fact, and therefore dishonesty, differs between science and other types of reckoning encountered in daily life. Yet even for those who did not see simplification in itself as dishonest, there was a widespread view that it could at least be used as a means by a researcher to be dishonest (see Appendix B for free response answers to question 7).

All categories of survey takers who suggested they would perform research indicated that they would spend more than twenty percent of their work on communicating results. None of the six largest categories of survey respondents indicated that they would spend less than forty percent of their effort on communication. Ironically, the lowest and second lowest groups for average effort-on-presentation also had the second highest and highest percent indicating that they planned to do research (High Responders and Male Scientists). These groups were also the ones that spent considerable time communicating their ideas in written format via the survey itself, relative to other groups that merely claimed they would spend more time communicating. Perhaps this result is justifiable in that these two groups plan to spend more time on the research *per se*. Non-scientists indicated that fifty-three percent of their effort would be spent on communicating research, showing that non-scientists consciously value communication more than scientists. This is consistent with the result that non-scientists strongly agreed with the statement that research can benefit from presentation, while science-majors only moderately agreed (average 7.48 versus 6.4 on a ten point scale respectively). Overall, the amount of effort future researchers plan to spend on disseminating their ideas is very high. This dispels the notion that the population of student researchers views communication as unimportant.

When closely scrutinized, the data yields several puzzling results. A hypothetical perfectly average participant implicitly contradicted herself. All partitions of the data containing more than ten respondents tended to agree with the sentiment that research that had a considerable amount of time invested in presentation was likely to have increased value. Time invested in a project is certainly an indication of personal commitment. Hence a researcher who spends considerable time on a presentation is likely to have a large personal commitment to that research. Yet on the very next question only three survey takers identified personal commitment as being possibly neutral; the rest eagerly viewed personal commitment negatively. While it seems obvious that the quality of research increases with effort, the question survey takers received dealt exclusively with the human aspects of that research. Survey takers consistently identified communication as a weak point of science, based on the results of question eleven. Question eleven asked how science may suffer from personal commitment, but never mentioned communication. Seventeen responders explicitly defined communication as the step where personal commitment most caused science to suffer (most responses to question eleven were too ambiguous to put into any one step of a scientific investigation, see Appendix B). While not the obvious majority opinion, many students are aware that scientists with compromised objectivity may express their "bias" in communication.

> Be it stem-cell therapy, cloning, climate change, genetically modified foods, or nuclear energy, if science is to stand a chance of not being completely beholden to the most powerful political entity, scientists must speak for themselves. They must speak to the public and they must speak to each other, and they must speak eloquently.

Two questions dealt with essentially the same subject on the same rating scale, yet produced answers on opposite sides of neutrality. Respondents replied slightly in the affirmative that results could change (or seem to change) based on presentations, yet replied slightly in the negative that the researcher could change findings in the natural sciences (see questions five and six). If results can readily be changed by presentations, then the researcher, who makes the presentation, should have sufficient room to interject their own subjectivity. This logical conclusion was not reached by the average survey taker. If the average contradiction is not an artifact of the analysis method, one possible explanation for this contradiction is that survey takers defaulted to an assumption that the natural sciences are done *during* research and hence not vulnerable to subjectivity introduced during communication. This contradiction is evidence that science is viewed as mostly independent of its transfer. The transfer is seen as independently corruptible. Students equate the study of objective reality with objective reality itself.

Respondents returned to the theme of bias many times in the free response section. This was despite the lack of the word "bias" anywhere in the survey. A typical reply to question eleven is that given by respondent twenty: "The research could become biased and therefore invalid" (see Appendix B). The frequency respondents associated bias with science suffering implies that it is widely recognized that bias is harmful to science, confirming that not only do most people believe science *is* objective, but also that it *should* be objective. Perhaps avoiding bias is viewed as the primary condition for an investigation to be considered scientific. Respondents may have been guided overwhelmingly to mention bias in association with the term "personal" (see question eleven in Appendix A); science is meant to be done for a greater good, not for personal gain. Unfortunately, the survey did not explicitly deal with the perception of the goals of science itself. Yet the nature of most research requires long-term investment by scientists.

Conclusion

The most significant finding is that students in general are keenly aware of the demands that will be placed upon them when they must communicate their work. STEM majors are no exception. This is in direct contradiction to Edmonston, Dawson, and Shibeci's findings that STEM majors do not appropriately value communication (Edmondston, Dawson and Schibeci 2462). In addition to stating that they would expend roughly the same effort on communication as non-science majors, science majors actually *wrote more* on the survey itself. If nothing else, this indicates strongly that STEM majors are interested in scientific communication.

Large expected differences between STEM and non-STEM majors in relation to specific questions on the survey were not borne out overall. Gender proved to have much more influence on how a participant responded. The peripheral finding that female science majors were much less likely to mark that they planned to do research in their future may be a good subject for further investigation. Fundamental differences in understanding not addressed by the survey may underlie how students responded. Future research could also clarify students' understandings of what the purpose of science actually is in order to contextualize their responses about dishonesty and bias.

Students are aware that researchers take an active role in their work even after all data has been collected. They are also aware that this involvement can have both positive and negative consequences; participants indicated that presentation benefitted results *and* that researcher involvement could cause results to suffer. While it may be that there exists a wide perception that science itself is ideally free from human influence, based on the results of my survey it can be inferred that a significant number of students realize that scientists themselves are not wholly objective.

Ultimately, how those at the forefront of science and technology transmit and alter what they discover is the focal point of our most passionate controversies. Be it stem-cell therapy, cloning, climate change, genetically modified foods, or nuclear energy, if science is to stand a chance of not being completely beholden to the most powerful political entity, scientists must speak for themselves. They must speak to the public and they must speak to each other, and they must speak eloquently. Debates on these issues generally do not focus on the scientific method as it should be practiced, but rather on how that method has been usurped to serve a claim. My research has shown that students across all interests are similar in how they view scientific communication. In that, at least, they can find common ground when debating problems that shape the future.

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Appendix A

Summary of Survey with Demographics

Q #	Abridged Survey Questions	All Data N = 52	Male Scientist N = 14	Female Scientist N = 12	Female Scientist > 3 yrs. College, N = 4	Male Scientist > 3 yrs. of College, N = 7	Male Scientist < 3 yrs. College, N = 7	Female Scientist < 3 yrs. College N = 8	All Scientist N = 26	All Non-Scientist N= 26
2).	Years College *	2.63	3.14	2.08	3.50	4.79	1.50	1.38	2.65	2.62
4).	Completed English requirement	40.00	12.00	7.00	4.00	6.00	6.00	3.00	19.00	21.00
4).	Not Completed English requirement	12.00	2.00	5.00	0.00	1.00	1.00	5.00	7.00	5.00
4b).	English useful to scientific writing *	5.41	4.42	5.86	7.00	3.50	5.33	4.33	4.95	5.85
5).	Presentation of data will alter content *	6.60	6.29	6.75	7.00	6.00	6.57	6.63	6.50	6.69
6).	Subjectivity in scientific experiments *	4.87	3.86	5.08	5.75	4.29	3.43	4.75	4.42	5.31
7).	Believes science suffers when simplified	14.00	7.00	2.00	1.00	3.00	4.00	1.00	9.00	5.00
7).	Not believes science suffers when simplified	38.00	7.00	10.00	3.00	4.00	3.00	7.00	17.00	21.00
7c).	Simplification results in dishonesty	25.00	6.00	7.00	3.00	4.00	2.00	4.00	13.00	12.00
7c).	Simplification does not results in dishonesty	26.00	7.00	5.00	1.00	3.00	4.00	4.00	12.00	14.00
8).	Scientific dialogue = everyday conversation *	5.54	6.00	5.75	5.75	5.71	6.29	5.75	5.88	5.19
9).	Plan to do research	31.00	13.00	6.00	2.00	6.00	7.00	4.00	19.00	12.00
9).	Not plan to do research	21.00	1.00	6.00	2.00	1.00	0.00	4.00	7.00	14.00
9).	If yes to research % time on presentation prep	48	43	46	90	36	50	24	44	53
10).	More time on crafting data = better results *	6.94	5.92	6.92	9.75	7.29	4.33	5.50	6.40	7.48

* = Averaged results based on 1 - 10 scoring

RESULTS: ACCUMULATED DATA N = **52**

1). Are you in a program that is part of the College of Science or College of engineering and Computer Science?

Yes 26 No 26

1b). If you answered "Yes" to 1, what is your major? See appendix for list of majors

2). How many years have you been attending college? Average # of Years 2.63

3). What is your gender? M 26 Fe 26

4). Have you completed the English/Communication requirement for your deg 40 Yes 12 No

4b). If you answered "Yes" to 3, how applicable was the content of those English/Communication courses to scientific writing? 1=no relevance, 10=extremely relevant Average 5.41

5). How much do you believe the presentation of scientific findings can alter the actual content of those findings? Integer answers 1-10 (1 being no influence and 10 being the presentation of findings being the primary influence on those findings). Average 6.60

6). How much room for subjectivity do you believe exists in chemistry? In other words, to what extent do you think the conclusion drawn from an experiment depends on the personality etc. of the researchers involved? Integer 1-10, with 1 being "no difference/completely objective" to 10 "infinite room/almost sole influence". Average 4.87

7). Do you believe that content related to a scientific or engineering principle always suffers when it is translated into a form understandable to a non-expert? 14 38

7b). If "Yes", In what ways does the content suffer? See list comment to this question in appendix A

7c). Does simplification ever amount to dishonesty? 25 27
Elaborate if necessary: See list comment to this question in appendix B

8). How comparable do you believe the purpose of scientific dialogue is to the purpose of conversations in everyday life? Rate: 1=not at all comparable to 10=highly comparable Average 5.54

9). Do you expect to do research or present new technologies in your career? If yes, please indicate how much effort you plan to put into crafting presentations as a percentage of the total effort involved in a research project.

Yes 31 N 21 48 % Of your effort if Yes

10). How much do you agree with the statement that the more time a researcher spends on crafting their argument, the more valuable their findings become?
Rate: 1=do not agree to 10=enthusiastically agree. Average 6.94

11). In what ways can science suffer when researchers have a personal commitment to their research?
See list comment to this question in appendix C

Appendix B

Survey #	In what way can science suffer when researchers have a personal commitment to their research?
1	[no comment was provided]
2	The researchers may become biased in their analysis and presentation of findings. it is important in many ways to remain [objective] when conducting scientific research
3	They are unlikely to give up when or if necessary to proceed in productive findings
4	The scientific findings could be interpreted and presented in way that only benefit or present fact relevant to the personal commitment
5	Sometimes the researcher may see things in their research that isn't really actually there.
6	Sometimes through time the information of the research may become biased.
7	It probably probably to make science suffer
8	If the person has a personal commitment, it's possible they could keep it to themselves, and not reveal the new knowledge.
9	It depends on the type of research and the type of "personal commitment". A lot of researchers conduct research to increase their number of publications. Other researchers may be dedicated but they pursue work that has already been explored tremendously by other scholars. This translates to a waste of time and a lack of improvement.

10 Look at the anti-vaccine idiots. Several recent deaths in California because of it.

11 It can suffer from paranoid personal bias and/or falsification of experimental data.

12 Personal commitment can make science suffer because it interferes with the research.

13 Because they become too emotional about their research.

14 Sometimes if they put too much time and or effort in one part of research another part may suffer. There is always a need for more research and experiments.

15 A scientist should always try to disprove their hypothesis. If a scientist wants his hypothesis to be true for personal gains, he may not put full effort into disproving his theory to ensure it is strong before he presents it. A good scientist is impartial to his findings.

16 I disagree with this statement

17 Personal bias... human emotion clouds judgment.

18 People use emotional connection to justify changing interpretations and results.

19 I don't think science suffers from committed researchers. In my belief, science actually grows further with committed researchers.

20 The research could become bias and therefore invalid.

21 If researchers have a personal commitment to their research, they risk making mistakes, or distorting the truth in hopes of getting the answer they want.

22 Science is an objective study, not a subjective field, such as philosophy can be. When emotions become involved, results can be skewed, or biased to match the current subjective intent of the researcher. By keeping a stoic approach (not to say enthusiasm should be omitted) true honest results can be recorded accurately.

23 -Science may not be understandable to for the layman if a researcher has become so engrossed in research
-Researchers might concentrate on only one topic they feel most committed to. Other topics would be ignored. Researchers might want to prove their hypothesis, so their findings might be bias based on past experiments, or experiments might be engineered or falsified to support those findings.

24 Some facts may distorted and/or omitted to prove the point the that is taken very close by the presenting scientist/researcher.

25 Lead to bias to get get to their desired outcome.

26 When you are personally looking for a specific answer, you might be more inclined to sway the research in that direction.

27 Everything is biased, science is no exception when a researcher includes bias in their findings or their topic of research, the conclusions will be inevitably be skewed.

28 Scientists are trained to objective, but the moment research is taken to a personal level, the possibility of biases becomes more apparent.

29 Bias.

30 Sometimes if people are over committed or emotional about something they may skew their findings.

31 I Don't Know.

32 [no comment was provided]

33 Research can be biased

34 The results can become extremely biased

35 It becomes more "personal" than "scientific". Taking emotions out will help make it less bias.

36 All researchers have an investment in their research, but the truth and facts become clouded when there is an investment in the conclusions. Science works best when impartial.

37 Too much personal commitment can create bias. This should be kept in check by others performing similar experiments, if not they may falsify their results.

38 Scientists may over look important that isn't as obvious when you are so involved in your own findings.

39 I feel like a personal commitment to research can make better results.

40 Researchers might want a specific answer and so their research could possibly be misconstrued.

41 Researchers may have a personal bias to their research.

42 It would be biased

43 I think scientists try to be as separated from their research as possible, I don't feel that their personality has anv effect on research

44 It depends, some researchers can throw their arguments to prove a points, which can undermine the legitimacy of their findings.

45 They become biased to their research, therefore they can be negatively influencing the outcome. When this happens, results become less accurate.

46 Researchers may become bias to the subject

47 Scientists who become too devoted to their research may fall into a rut, which hinders them from completion. It is also possible that a hypothesis, study, or principal of experimentation may be rushed, resulting in a incorrect information or incomplete works.

48 Sometimes when one is personally attached to something, we tend to not be completely unbiased in our research.

49 [no comment was provided]

50 Results can be altered/skewed in favor of the researcher's hypothesis so they can say they were correct.

51 Scientific observations could become bias among researchers.

52 The research can in some ways be 100% more effect or completely biased and unreliable, but there is no in between.