Integrity in Scientific Research and Writing

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In 2000, Sigma Xi published the excellent small booklet *Honor in Science* for masters-level students beginning their first experience with full-scale research for publication. The need to present these concepts to a younger audience has grown as the Internet has increased the incidents of plagiarism. Online publication and rapidity of access to the literature has posed new challenges to peer review and assignment of intellectual debt. This publication is designed to address these issues for a new generation of young aspiring scientists and their K-12 and university teachers who bear an important responsibility for instilling a sense of honor and integrity in scientific research and publication. This smaller publication avoids major discussions on whistleblowing and institutional policies dealing with "big science" fraud, and introduces Internet Age problems, hedges, indirect citation, and strategies for science teachers who are setting the first standards for young science students. This *KSN* also draws heavily upon and expands the Schrock and Yang article "The Growing Problem of Plagiarism and the Current Use of Science Citation" that was published in Chinese in 2007 (*Shengwuxue Jiaoxue* 32(7): 14–17). Bill Jensen provided important review comments. -JRS

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Front Cover: Recording data in ink in a bound lab or field record book is a fraud security measure lost when newer easily-altered electronic formats are used.

Integrity in Scientific Research and Writing

No human enterprise has been more successful than science. The difference between modern life and the struggle for survival in the Stone Age is due to science discoveries. However, these discoveries would have little effect if they were not communicated at large. A personal discovery kept to oneself dies with the discoverer. Therefore the dissemination of science knowledge is necessary and is an integral step in the advancement of our science knowledge.

How is Scientific Research Different?

Science is "playing upon the surface of the real"—that is to say: science is restricted to the examination and explanation of natural phenomena. These phenomena are universal—gravity does not work differently in Europe than in the United States. And science assumes cause-and-effect relationships exist that can eventually be explained. This means that if a current science explanation is not quite correct, future research in time will correct the error.

How Is Scientific Writing Unique?

Unlike literature, science writing uses precisely-defined terms and is careful in generalizing beyond the limits of the experimental results.

Science journals often use a traditional, human-invented convention of structuring the scientific paper into sections: introduction and previous work, hypothesis or proposal, materials and methods, results devoid of interpretation, and a concluding discussion.

Examination of articles in a target journal provides a writer with a sense of the conventions that contemporary scientists expect in that subdiscipline. And the nature of science always constrains us to use precise language.

Why Are References Important?

Research builds upon what is already known, even if our conclusions challenge the present understanding. But we never come to a problem with an empty mind. At this time in history, there is already something known about nearly all natural phenomena. Usually, we cannot begin to ask a question or form a hypothesis without knowing what is already known. We are nearly always starting our research where others have stopped. The prior knowledge we bring to our research constitutes an "intellectual debt." When we describe how we are setting up our inquiry, we describe the source of each important contributing idea by citing prior research in the text and listing the full reference at the end of our manuscript.

Must Every Concept Be Referenced?

No. Classical major themes that will be recognized need not be cited. For instance, every time you mention "evolution," it is not necessary to cite "(Darwin, 1859)" in the text and list the *Origin of Species* in the references. All modern biologists recognize this major concept and no one is going to credit you with its discovery.

However, literature covering the distinct lineage of discoveries leading to your research should be cited. Major omissions of critical references may indicate your research is premature or naive, and may justify an editor or peer reviewer rejecting a paper for publication (Kochen, 1989).

References also direct a reader to further related research. Comprehensive references provide an excellent method for a beginning student to expand their knowledge of a field.

What is "Priority?"

A unique thrill in science is the privilege of being the first to discover a new phenomena or concept. The first time a new species is described, that name has priority. And the first person to describe a new concept should have priority. The recognition of priority is important and is reflected in future references that acknowledge the origin of ideas.

What is Language Imperialism?

Sometimes a researcher makes a discovery and publishes it in a foreign language journal that few researchers read. Another researcher makes the same discovery much later and publishes in an English language journal—and gets the credit. This is called "language imperialism." In serious research, a thorough search of the literature should have been made, including other major languages. The recent trend to drop foreign language requirements in doctoral programs perpetuates language imperialism (Schrock, 1987).

Are References Bibliographies?

No. Most journals use "References" or "Literature Cited" strictly for those items cited in the text. So all text citations should be referenced and all references should be cited.

A "bibliography" is a list of all relevant publications. This may occur in a review article that is summarizing the state of the field of study at this time.

"Further reading" merely provides a list of related articles and is rarely used in primary science literature.

What is "Primary Literature"?

Articles that appear in science journals and are the first report of original research are primary sources. In modern times, primary sources are also peer reviewed. Review articles and textbooks that summarize the current state of a field may reference these primary sources. Textbooks, news releases, and popular magazine and newspaper accounts of research, no matter how current, are not primary literature.

What is "Significance" in Science?

When non-scientists observe that something appears "significant," they usually mean that it stands out as somehow important. To a scientist, a "significant" result is a result that is mathematically unlikely to be random.

When research depends on mathematical analysis, it is important that a researcher use appropriate statistics.

Gordon R. Sherman in *Honor in Science* states this best: "...when using computing equipment, researchers certainly should personally be able to carry out in concept the computations that the computer produces or be working with a colleague who can. They should really understand the algorithms they use. It would be healthy for all researchers to develop automatic skepticism that a software package actually performs the algorithms as the researcher understands them. They should really understand what computations are carried out inside the machines they use."

It is also possible for experimental results to show a relationship by chance, especially if the number of test subjects is low. For instance, similar to flipping a coin where the coin comes up heads four times in a row, it is possible that a test being run four times could show a change compared to the control group if the number of trials is too low. Therefore, for some research, knowing the number of replications needed to get mathematically significant results is very important.

Are There Limitations on Experimental Subjects?

Animal Care and Use Committees (ACUC) at universities and other research facilities review research proposals involving covered vertebrates. In order to be eligible for publication, more and more journals are requiring researchers to provide the ACUC-approved protocol number in any manuscript involving covered animals.

Similar committees exist for approving research with human subjects.

Medical and pharmaceutical research has defined protocols on research that underpins medical drugs and procedures that are critical to human health.

Before WWII, research into nuclear fission was kept secret due to military implications. It can be dangerous to society at large for certain discoveries to be easy available to persons with bad intent. Therefore, more recent breakthroughs in ferret-to-ferret transmission of highly virulent bird flu similar to the deadly 1918 strain were not immediately released to the public in full detail.

Teaching responsible compliance with limitations on science and science publishing is an important duty of teachers and supervisors.

What is "Trimming*"?

Outlying data points can be more than pesky. They can ruin a perfectly good curve. Consider a biology class where a teacher wants to demonstrate the clustering of human body temperature, taken under-the-tongue. Each student is issued a thermometer with appropriate hygienic procedures and reports their datum point to the teacher who is building a narrow distribution curve around an average of 98.6° F. Then one student reports 27° !

To incorporate such an outlier into the data would skew the average human body temperature to a hypothermic 92° F. Should the teacher throw out the data point? If the thermometer is working correctly, this student should be dead!

Upon inspection, it is found that the student received a centigrade thermometer. The converted reading is nicely equivalent to normal.

Experimental procedures and equipment require oversight and care. Students should not be allowed to discard data without good reason. Monitoring of experiments and checking of equipment is also part of a science teacher's responsibility.

Sometimes outliers will be genuine data points that may reveal valuable exceptions, pose additional questions, and be the starting point for more research.

"It is not sufficient for the scientist to admit that all human activity, including research, is liable to involve errors; he or she has a moral obligation to minimize the possibility of error by checking and rechecking the validity of the data and the conclusions that are drawn from the data."

Honor In Science, 2000, p. 3

What is "Cooking"?

Sometimes data can resemble a random scatter of points. But if we apply some math manipulations, we might force it into the approximation of a line. There are many ways to "massage the data."

*In *Honor in Science*, Jackson describes Charles Babbage's concepts of trimming and cooking which are counterintuitive. A more teacher-friendly definition is provided here.

But unless there is a legitimate reason for performing the statistical manipulation, such "cooking" should not be done.

Legitimate procedures include squaring a difference from a mean and then taking the square root of the sums in order to determine standard deviation. This is legitimate since we are interested in how much our data vary from the mean regardless of whether the variation is above or below the mean, and the squaring-square root procedure keeps the values from "canceling out."

But no such mathematical procedure should be used if researcher does not understand why it is done.

This is why, even though complex math calculations are rapidly done with a computer, it is important to learn to do the math calculation by hand in order to understand the concept. Then when a computer program is utilized, there should be some general recognition of whether the resulting answer "makes sense."

One good method to validate a computer program is to also run a data set for which the outcome is known, to ensure that the computer analysis is not accepted on blind faith.

What Is Science Fraud?

From time to time, a case of science fraud appears in the news. The fact that this gains much attention indicates that it is fairly rare, and an unusual activity among scientists.

Fraud is the outright making up of data. One famous case involved the editor of a prestigious British journal who published a study of the IQ of a small set of identical twins reared apart. His conclusion was that IQ was 80 percent inherited. Such cases are obviously rare. But small numbers do not make a strong argument for "mathematical significance."

He eventually published larger data sets although the statistics for variation were identical, a highly unlikely occurrence. After his death, an examination of his notes revealed that he had merely scaled up his original data and there was no larger group of twins reared apart. Over the years, his conclusion about IQ has continued to be confirmed; without the access to his notes, it is unlikely the fraud would have been exposed.

Another notorious case involved a researcher at San Diego State University. When it was discovered that he published research that required far more experimental animals than he had, SDSU rightly required all co-authors to re-defend the research and print retractions if results were not confirmed.

"...a false statement of fact, made deliberately, is the most serious crime a scientist can commit."

C.P. Snow
(quoted in *Honor in Science*, 2000)

Early practice in making up data, and the attitude that it is okay to do so, may originate in our school laboratories. Far too many students confess that they have at some time in their schoolwork fabricated lab data. This may occur when the lab instructor takes too much time explaining the lab and does not leave time to finish the experiment. When an experiment requires data be taken every ten minutes, and eight data points are to be recorded, it will require a minimum of 80 minutes. But when the instructor blabs away about procedures and leaves only 50 minutes, students cannot complete the full graph on time. Yet, when the curve becomes evident, and the clock is running

out, it is far too common for students to submit a lab report including the last three points on the probable curve. This procedure, often called "dry labbing," is far too common. It is another name for recording fraudulent data. The instructor who accepts it, indeed was culpable in causing it, has encouraged the student in fraud.

This does not mean that every case of science fraud traces back to a lazy teacher or that a researcher cannot discover a method to commit fraud themselves. But the atmosphere of absolute integrity and honesty in science should be seamlessly present from the earliest science class onward though post-graduate work.

What Is "Replication"?

The "methods and materials" section of a research paper is very important. The procedures used must be described in enough detail that another researcher can conduct the experiment again, and presumably get similar results and reach a similar conclusion.

In fact, replication of research does not regularly occur. But in an area such as medical research where concepts rapidly build, a failure to be able to "take the next step" based on prior research may lead researchers to go back and replicate the prior research. If the results do not match, the original report may have involved experimental mistakes or misinterpretations, or the results may be intentionally fraudulent.

Some disciplines of science move rapidly and erroneous research is soon detected. Other areas may take decades or a century to replicate and correct.

There are however areas of research where the studies cannot be repeated. Evolutionary events cannot be re-run. Some high-cost physics experiments are too costly. And some field ecology may involve too many unknowns to ever be exactly replicable.

Replication of research makes science "self-correcting."

Are Negative Results Published?

It depends. The master's thesis is an important first experience in the early education of young researchers. It is common for some experiments to yield results that fail to support the hypothesis. Journals are hesitant to publish negative results. Such theses often sit on university shelves and are never published in journals.

But some negative results are important. In the first years of the AIDS epidemic, before the causative HIV agent was discovered, the reason for suppression of the immune system was unknown. Due to the prevalence of AIDS in male homosexuals, experiments were conducted injecting semen into the rectum of rats; the results were negative, there was no suppression of the immune system. But this was important to publish so research could proceed in other directions.

Science also moves ahead when scientists "close their minds" to ideas that do not work.

What is Peer Review?

When a science journal editor receives a manuscript, the editor sends it to several peer reviewers or referees. To get expert opinion on whether the article should be published, the editor selects reviewers who are experts on the research topic; sometimes they may be authors cited in the references in the research paper.

The job of peer reviewers is to judge the quality of the manuscript. Is the research valuable and does it add to current knowledge in the field? Are the methods used and the math analysis appropriate? Do the results justify the conclusions? Are there big gaps in the references indicating that the research is naive or has not considered the full range of previous related work? And since journals often serve narrow sub-disciplines, even if the research is solid and well-written, perhaps it belongs in another journal.

While peer review may detect problems such as numbers too low to produce significant results, etc., peer review is unlikely to detect fraudulent results.

What is "Open Peer Review"?

Under normal peer review, the reviewers are selected by the journal editor and they usually choose to remain anonymous. "Open peer review" includes reviewers' names on the peer review reports, and when/if the research article is published, the reviews are made available online along with the final version of the article. A "pre-publication history" lists the prior versions of the article along with the signed reviews and the author's responses to the reviewers. Early experiments with open peer review were conducted by *Nature* and PubMed Central. There are varying concerns with open peer review across various science disciplines and the use of open peer review remains limited.

How is Science Correctly Cited?

Science is both a body of knowledge about what is already known, and active research to discover new concepts to add to, and modify, that knowledge.

When a teacher asks a student to write a report about a science topic, the information will come from the ideas generated from prior researchers and reported in print. The teacher's purpose is to have the student comprehend what is known and organize or synthesize their understanding to demonstrate that knowledge.

When a student is actually engaging in original research, the research will be based on intellectual predecessors that set the context of the research. That prior work must be acknowledged.

How Should Electronic Sources Be Cited?

Studies indicate that in 15 months, 10 percent of citations to online sources are not retrievable (Dellavalle et al, 2003) and more recent studies show that this "URL decay continues unabated" (Wren, 2008). While the internet has made data bases and many journals conveniently accessible, there is no mechanism to ensure that the servers that hold these sources will be immortal. Indeed, the life span for electronic formats, software and hardware is usually less than a decade, requiring repeated migration to more modern hardware and software. This is a cost that is not posed by paper which, in acid-free formulation lasts for many centuries and is accessible via interlibrary loan from dispersed library archives. Currently there is no universal and accessible ILL system for orphaned electronic publications and it is unlikely that there will be in the near future.

Therefore, when an electronic source is used, it should always be followed by a last date of accession as in: [Accessed on July 11, 2013]

In addition, "wiki" sources that constantly change should be avoided. Science is built on the best thought that can be presented, and must be stable as a base for future work. Science publications represent the best of carefully thought out scholarly presentation, not a casual hallway chat.

What is Plagiarism?

"Plagiarism" occurs when a writer represents someone else's words or ideas as his or her own. While we generally visualize this as occurring in writing, where the writer steals the exact words of another, it can also occur when a researcher reviews a paper that has not yet been published and steals the ideas for use in their own research and publication without giving due credit.

There is little doubt that there has been a dramatic increase in plagiarism due to the ease of cutting-and-pasting material from the internet and other electronic sources, often called "technology driven plagiarism."

A writer most definitely can use another person's words and ideas, but they must acknowledge the source by either direct quotation or paraphrasing.

What is "Direct Quotation"

When a student finds that an author has "said it best," then it is possible to use those exact words in a **direct quotation.** Such word-for-word usage requires that the words be enclosed in quotation marks and the source clearly cited. Researchers will find that many journals and peer reviewers discourage direct quotation and expect the writer to fully re-synthesize earlier concepts in the new context of the article, but with credit.

In 2003, Chris J. R. Wilmott and Tim H. Harrison published "An Exercise to Teach Bioscience Students About Plagiarism" in the *Journal of Biological Education.* We can quote the following line as long as we use quotation marks and fully cite the article in the references: *"One reason for the renewed interest in plagiarism has clearly been the rise of the Internet as a source of material" (Wilmott and Harrison, 2003).*

What is a "Paraphrase"

When a source author has not "said it best" or when a student or researcher only needs to refer to the general idea briefly, it is far more common to summarize the source statement but there still must be a citation. In a paraphrase, the exact words of the source author have been generalized and no quotation marks are used: *Wilmott and Harrison (2003) believe the Internet is a factor in plagiarism.*

How Many Words Must Be Different?

It is common for a student to ask, "How many identical words in a row constitute plagiarism?" There is no set number of words, but each additional identical word in the same sequence as another source makes it more unlikely the wording is original.

But we are focusing on an attitude of honesty, not a legalistic counting of words. Generally, if a student or researcher is thinking "how many words must I change to make this statement not appear to be copied?"—the student or researcher is plagiarizing.

How is Plagiarism Detected?

Usually a teacher or scientist is familiar enough with a student or researcher to know the expected level of writing. When some words in an essay or science report are too elegant or refined to have been written by a beginner, this is the first indication this might not be original work.

Other signs include inconsistency in writing style and obvious errors such as text stating "as we first wrote in our earlier book," etc. Some writers who cut out text from online sources do not even take the time to read what they have stolen.

Since the student or researcher may have used the internet to access the questioned material, it is often just as easy for an instructor or supervisor to merely enter the written excerpt into a search engine and locate the source.

However, there are many commercial agencies that provide students with "research papers" supposedly for study but which are "paper mills." Commercial software tools such as Turn-It-In, EVE2, PlagiServe, WordCheck and others will often detect commonly supplied storehoused papers. More difficult to detect are ghost written papers customized to a student's directions. These are less common because they are expensive, and are more difficult to detect. A teacher may have to modify assignments so they are written in stages and turned in multiple times, or written in class, to ensure the work is the student's.

There is always the possibility that a student or researcher is genuinely elegant in their writing, and this possibility must be kept in mind. Along with honesty and integrity, human dignity is to be preserved.

What is "Double Publishing"?

Sometimes called "self plagiarism," double publishing occurs when a researcher publishes essentially identical research in different journals. "Double publishing" is a preferable term since the author is not representing other's work as his/her own.

This causes several problems. Publishing is an expensive procedure both in cost and manpower for editing and review. Journals nearly always state up front that they only publish original research that has not been published before. Therefore the author is breaking this agreement by submitting work multiple times. Some journals now require an author to sign a document attesting to the fact that they have not published it previously elsewhere.

In addition, if the work involves clinical trials, double publishing can give the false impression that a drug or procedure has undergone more testing that has actually occurred.

Double publication is more likely to be caught as more editors utilize plagiarism-detection software that also exposes this "copying from oneself."

What is a "Least Publishable Unit"?

Also called a smallest or minimum publishable unit, this is the smallest amount of information necessary to be accepted for publication in a peer-reviewed journal.

A thesis or dissertation may genuinely consist of several discrete experiments and conclusions. However, because the number of publications is often used to assess candidates for positions or promotion by supervisors who do not understand the research work, it has become more common for researchers to break up their results into smaller papers to be published separately to drive up their publication count.

What is a "Hedge"?

It is important to cite another scientist's conclusions with careful attention to the limitations, or "hedges," the scientist puts on those conclusions. For instance, research may show that a drug is forty percent effective reducing certain types of lung tumors. A student reporting on this may quote or paraphrase it as "being effective against lung tumors," failing to include the limitation to "forty percent" or to just "certain types."

Horn (2001) describes this problem: "When scientists cite and paraphrase the conclusions of past research, they often change the hedges that describe the uncertainty of the conclusions, which in turn can change the uncertainty of past results."

What is "Indirect Citation"?

A student or researcher may locate an idea expressed in a book that in turn has

Plagiarism Exercise (after Willmott and Harrison, 2003)

Source Wording from Dellavalle *et al.*, 2003:

The percentage of inactive Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication.... Although our study many not be representative of the entire field, Internet references occurred frequently and were often inaccessible within months after publication in the highest-impact U.S. medical and scientific journals.

STUDENT/RESEARCHER WORDING	PLAGIARISM? YES/NO
1. "The percentage of inactive Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication.... Although our study may not be representative of the entire field, Internet references occurred frequently and were often inaccessible within months after publication in the highest-impact U.S. medical and scientific journals" (Dellavalle *et al.*, 2003).	
2. The percentage of inactive Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication.... Although our study may not be representative of the entire field, Internet references occurred frequently and were often inaccessible within months after publication in the highest-impact U.S. medical and scientific journals (Dellavalle *et al*, 2003).	
3. The percentage of inactive Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication.... Although our study may not be representative of the entire field, Internet references occurred frequently and were often inaccessible within months after publication in the highest-impact U.S. medical and scientific journals.	
4. The percentage of missing Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication.... Although this may not be representative of the entire field, Internet references occurred a lot and were often gone within months after publication in the highest-impact U.S. medical and scientific journals.	
5. Missing Internet references increased from 3.8% at 3 months to 10% at 15 months and to 13% at 27 months after publication. Although other fields may have different rates, Internet references occurred a lot but were often gone within months after publication in our most-important scientific journals.	
6. According to Dellavalle *et al* (2003), Internet references reach 10% by 15 months after publication. This problem with disappearing references was found in some of our most important science journals.	
7. Dellavalle *et al* (2003) tracked the disappearance of Internet references in several major medical and scientific journals and found the Internet references disappeared by 10% in the 15 months after publication. However, they note that their study may not apply across all fields of science.	

Answers to the Plagiarism Exercise:

1. The first version is correct. The quotes indicate all words come from the source, and the source is cited (and we assume fully cited in the references at the end of the writer's essay).
2. This version is plagiarism. The writer has used exactly the same words as the source without quotes. Although the citation is given, we would wrongly assume the writer paraphrased the statement.
3. This version is plagiarism. The writer has used exactly the same words as the source without quotes. Without any citation, we would wrongly assume the writer originated this idea him/herself.
4. This version is also plagiarism. Although the writer has changed a few words, we would wrongly assume the writer originated this idea him/herself.
5. Although the writer has changed even more words, the writer has not put the concepts into his/her own words. Without a citation, this is probably plagiarism.
6. This version is a paraphrase that is cited, but the paraphrase removes the "hedge" used by the original author to indicate that there is a limitation. The paraphrase makes the conclusion seem unlimited and certain. This is not plagiarism but can be misleading to science.
7. This version is correct. The writer makes a good attempt to understand the concept and put it in his/her own words, and also references the source of the writer's synthesis.

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been cited from another book. In writing the new paper, the writer simply lifts the words or ideas from the book, repeating the citation, without going back to the original cited source to check the original wording and context.

This is a common practice and does not technically violate any rules or code of conduct. But such a line of serial quotation going back through many authors, each of whom have used the quote in their own context, has the danger of distorting or drifting away from the meaning intended by the original source.

At the least, it is laziness by the current writer. At the worst, it may be unknowing misuse that is now completely inappropriate, and provide weak or unjustified support for the present conclusions.

Using a clever method for tracking repeating citation errors, Simkin and Roychowdhury (2002) estimate that "... only about 20 percent of citers read the original."

What is Patch Writing?

Teachers and researchers may have empathy with plagiarists because when we were elementary students, we may have written reports that were copied with minimal modification from encyclopedias and other sources. Some of our early learning to write involves copying writing. But that habit should be broken as the student matures to write in their own words.

"Patch writing" consists of patching together chunks of copied text. Unless the material is correctly quoted or paraphrased and cited, it is plagiarism.

Even if the writer does put all the chunks

in quotes or paraphrases it, and provides proper references, it is seen as cut-and-paste writing. The purpose of assigning a student to "research" a topic in the library and write a paper is to demonstrate the student's ability to comprehend the concept(s) and incorporate that understanding into a broader synthesis. Patch writing fails to show if the writer comprehends enough to put the concepts into his/her own words.

Why Are Articles "Retracted"?

Honest scientists can make mistakes. Equipment can malfunction. Small data sets may not represent the wider natural phenomena. Additional work may expose methodological weaknesses and alter prior conclusions. In these cases, it is necessary to "set the record straight" so future researchers are not misled and resources and time are not wasted.

And when fraudulent science is discovered, co-authors have a responsibility to likewise retract the erroneous article. However, a retraction at a later date may not be read by researchers who only saw the earlier original work. A retraction is a weak solution to problematic science. It is far better that the weak or fraudulent science had never been published.

Who Gets Credit?

In some disciplines of science, researchers work in teams. One may have written the big grant, another managed the laboratory facilities, another performed the experiments, another cared for the animals, and another conducted the math analysis. So who gets credit on the author line? Because the importance of these roles varies by research project, that judgment must be made on the extent of contribution and its importance to the science reported.

It is widely acknowledged that there are often more authors on papers than is justified. Much of the blame for this rests with university and government administrators who have no understanding of the value of research in evaluating a scientist, aside from counting the numbers of papers published. This has led to inclusion of too many authors.

The question of who deserves to be listed among the authors is well-described by Broad and Wade (1982):

"First, all people named as authors should have made a definably major contribution to the work reported. Any minor contribution should be explicitly acknowledged in the text of the article. Second, all authors of a paper should be prepared to take responsibility for its contents in precisely the same measure as they stand to take credit."

Simply, any individual listed under authorship should be able to defend the integrity of their portion of the paper.

"'Appropriate recognition' means what it says. We are not ordinarily required to acknowledge in print the services provided by our typists, lab assistants or equipment suppliers, but those whose careers and reputations depend, like our own, on intellectual qualities and scientific ability deserve recognition. Not to give it is dishonest."

Honor in Science, 2000

What Are "Acknowledgements"?

"Acknowledgments" is an underused

final section of a research paper where credit can be given to those who provided minor assistance such as supplying specimens, advice, editing or proofreading, etc. It is also important to recognize the sources of funding for the research and this is the place for that.

This section also provides an opportunity to spell out the individual distinct contributions of authors, although this is rarely done.

Individuals listed under "acknowledgments" only are generally not responsible for speaking to the integrity of the paper.

What is a Teacher's Responsibility?

Science depends on honesty and trust. There are no "science cops."

Students come to science classes to learn not only what is already known, but also how to construct and perform experiments in lab and field. During the time that we as science teachers have oversight of their education, it is our responsibility to help them learn to "play on the surface of the real" honestly and with respect for the ethics of science.

We must help them understand the role of giving due credit, of acknowledging intellectual debt, of taking careful records and reporting truthfully what they detect by observation and reason. Senior scientists have a responsibility to model integrity and teach young scientists to work honestly.

We have a responsibility to oversee their work with rigor while we have that oversight, so that when they are on their own and are no longer being watched, we can trust them to continue solid research.

Just as there is no room for science fraud, there is no excuse for the teacher who looks the other way because confronting a cheating student is "uncomfortable." Accepting wrong data because we failed to check their experimental equipment is professional laziness. Allowing and even forcing students to "dry lab" part of an experiment because we do not allow them enough time is professional incompetence.

Science aspires to high standards. --And so does science teaching.

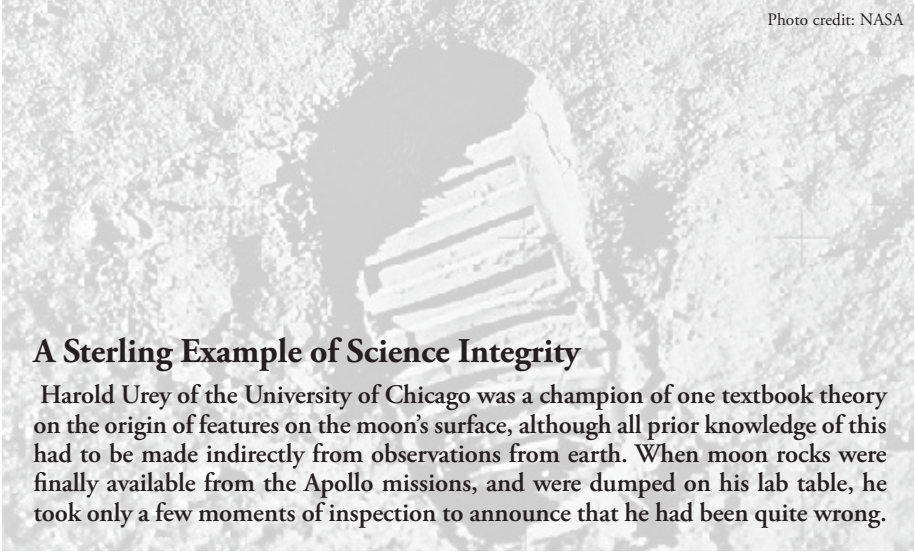

Photo credit: NASA

A Sterling Example of Science Integrity

Harold Urey of the University of Chicago was a champion of one textbook theory on the origin of features on the moon's surface, although all prior knowledge of this had to be made indirectly from observations from earth. When moon rocks were finally available from the Apollo missions, and were dumped on his lab table, he took only a few moments of inspection to announce that he had been quite wrong.

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Peer review, along with careful proofreading and attention to journal format as described in "Instructions to Authors," are vital steps in science publication.

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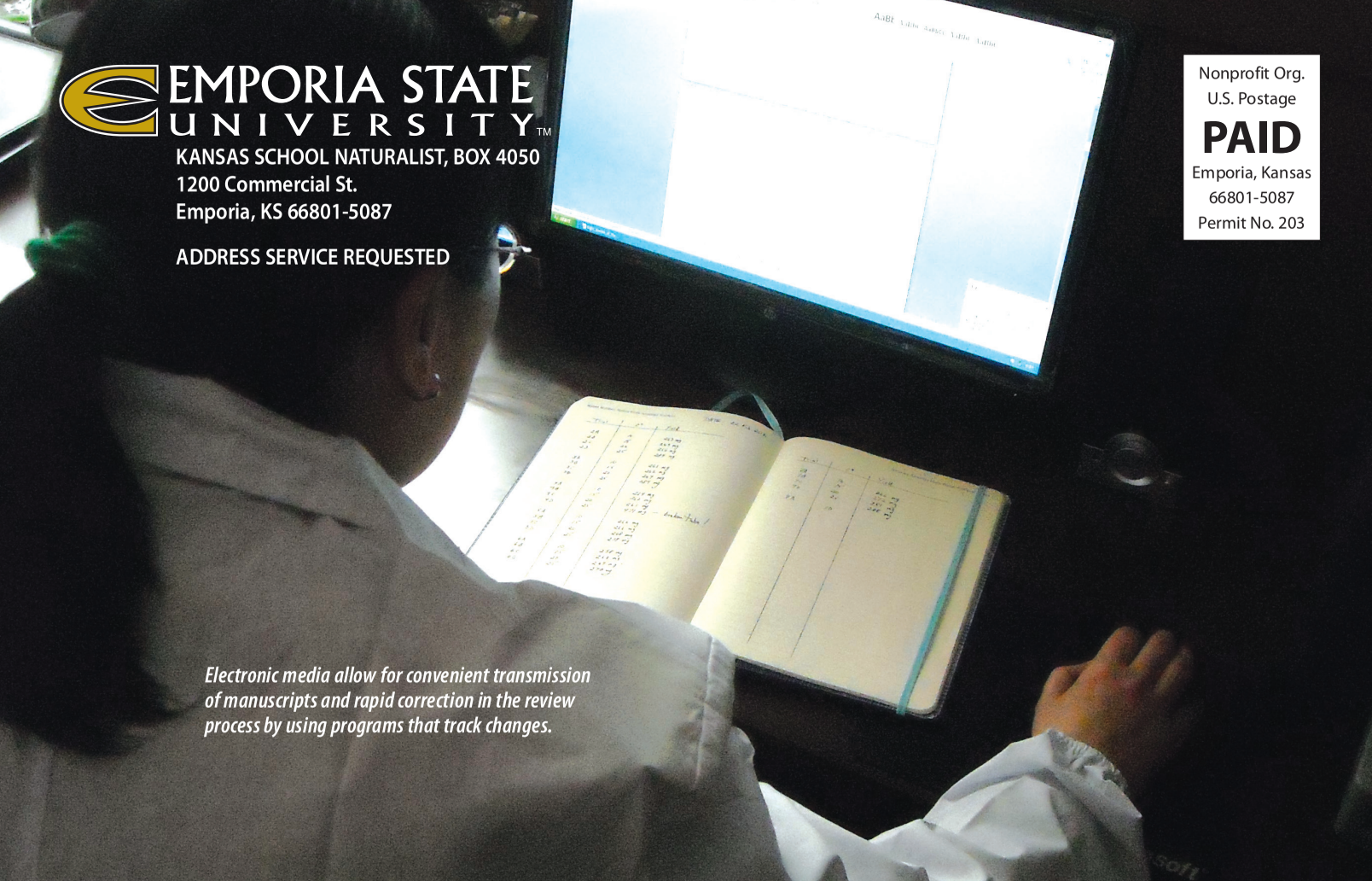

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