Materials Science & Engineering

Manual for

Graduate Students

Department of Materials Science & Engineering

Missouri S&T

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BASIC RULES

1. **Study this information carefully as <u>you will be held responsible</u> for any problems that arise due to lack of compliance.**
2. **It is expected that you WILL clean up after yourself in the labs (beakers, jars, countertops, etc).** (See comments from Coach John Wooden in Section I.H.)
3. **All samples need to be clearly labeled for safety and disposal purposes.**
4. **If you use any departmental equipment, please note that there are log books that must be signed.** (Some equipment also has a signup book to reserve a time to use it. You must do this to in order to use the equipment.)
5. **If equipment is not working or you break it, please REPORT IT to the main office (222 McNutt).**
6. **If you have any questions that are not answered in this manual, please check <u>first</u> with your advisor. If your advisor does not have the answer, or is unavailable, please see someone in the main Office.**
7. **Purchasing information (procedures for how to buy lab supplies) is reported in Section I.J. You should be familiar with these procedures as there are financial implications.**
8. **Rooms 142 and 253 McNutt are <u>teaching</u> labs and <u>may not</u> be used for graduate research experiments. The supplies (gloves, beakers, etc.) maintained in these rooms are also for undergraduate teaching ONLY! DO NOT "borrow" any equipment from these rooms (balances, scales, etc.).**

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I. General Information and Regulations

A. Introductory Information

1. International Students

All international students MUST follow SEVIS regulations. Please go to the International Affairs website (http://international.mst.edu) if you need more information so you do not become "out of status". You are responsible for knowing and following these regulations, which may impact your ability to remain in the US to complete your studies.

2. All Graduate Students

Orientation - All new graduate students must attend the presentation "Orientation for New Students" given by the MSE Associate Chair for Graduate Programs to be held at the beginning of each fall semester.

Sexual Harassment – Each graduate student on payroll will be responsible to take and pass the Preventing Sexual Harassment survey/exam.

-- Login to the "myHR" site at myhr.umsystem.edu. ("myHR" may also be accessed from the human resource services homepage at hr.mst.edu/index.html.)
-- Enter your user ID and password.
-- Click on "Self Service." Found under Navigation bar in top right corner.
-- Click on "Training."
-- Click on "myLearn
-- Log in with user ID and password.
-- Click "continue to myLearn"
-- Click on "Learning Plan"
-- A list of recommended training will come up, complete training as directed.

Pop-up blocking must be disabled for "myHR" to allow the online training program to load properly.

Per Policy Memorandum I-29a, all employees are required to successfully complete the "Preventing Sexual Harassment" interactive computer training program on an annual basis. ***(Be sure to take the Supervisor's exam.)***

Safety and Environment – Each graduate student is required to take and pass the Environmental Safety Test/Training which can be done through the internet. If you have not already received notification of this training via email, please let Admin know. Here is the link to the General Laboratory Safety Training (GLST) https://ehs.mst.edu/trainingindex/.

Lab Cleanliness – Each graduate student will be responsible for cleaning up after themselves and obeying university, state and federal requirements and regulations. See Lab Cleanliness Section (I.H) and the Safety Manual (Section III).

Academic Tenure Regulations – Because graduate student appointments are considered academic appointments, students are required to visit the following website for information on academic tenure regulations. ALL current

graduate students must read these regulations. Please go to: http://www.umsystem.edu/ums/rules/collected_rules/faculty/ch310/310.020_Regulations_Governing_Application_of_Tenure.

B. MSE Associate Chair for Research

The MSE Associate Chair for Research (ACR) – formerly known as Associate Chair of Graduate Studies – serves as the graduate program coordinator and is the initial point of contact for graduate students arriving on campus. The graduate program coordinator is the authority on regulations and procedures pertinent to the graduate program and should be contacted whenever questions or problems occur. They are also responsible for signing **ALL** graduate forms as "Department Chairman".

C. Policy on Ethics and Academic Honesty

The effectiveness of the research infrastructure throughout the work is based on the personal and professional integrity of the people involved. The basic assumption that is central to all research endeavors is that the researchers have done what they say they have done. The Department of Materials Science and Engineering is part of this infrastructure, and the research conducted here must withstand the highest scrutiny. Consequently, we must all ensure that our scholarly work is conducted and reported with the highest ethical standards. We must be careful in our record keeping and diligent in our efforts to attribute credit when we utilize the work done previously by others. In particular, we must guard against any activity that calls into question our integrity. In this regard, we affirm that:

- Information in a research program will be truthfully presented, and
- The work of others will never be misrepresented as our own

Students are encouraged to read more about research ethics at the following website https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm, which is associated with the National Institute of Health and has linked to numerous codes and policies on research ethics. An article from the Chronicle of Higher Education regarding the detrimental impact of plagiarism, which is viewed as academic dishonesty, is included in Appendix C. Also included in Appendix C is an article reprinted from the Industrial Physicist regarding research fraud.

D. Equipment Usage

The departmental equipment is available for student use based upon availability. The procedure to be followed is:

1. Identify the equipment needed,
2. Check availability and sign up for time to be used (if sign up log is provided),
3. Talk to your advisor before using equipment to check procedures and account information needed for use.
4. If the piece of equipment requires training (as noted on log sheet), please check with the main office on who to see for training BEFORE usage.

All equipment for which a use fee is charged will have a log requesting information on the account to be billed. You MUST log all equipment usage, even for class. If a piece of equipment is found to be operating without proper signature of the log book, the run will be stopped.

Contact your faculty advisor for the availability of other non-departmental equipment.

E. Registration Guidance

Prior to registration for the first semester of study, all new graduate students must report to the graduate program coordinator or their advisor, who will help them with their initial plan of study. All graduate students must complete one of the following forms, as appropriate: Form 1 (M.S.) or Form 5 (Ph.D.) Program of Study form. For subsequent semesters, students should register for their classes during the priority registration period after meeting with their research advisors. This is accomplished using the on-line registration capabilities offered at Joe'SS (https://joess.mst.edu). Completion of the plan of study will facilitate the registration process. During the fall and winter semesters, a full-time graduate student will be enrolled in 9 hours of course work and research and during the summer session for 3 hours of research. For their final semester on-campus, all graduate students may enroll for a reduced load (3 hrs minimum), provided that the requirements of their plan of study are still met. If an international student anticipates reducing their credit hours during their graduating semester, they will need to fill out the **"Reduced Enrollment Request"** form located at: Forms – The Office of International Student and Scholar Services | Missouri S&T (mst.edu) Further information may also be found in the Graduate Catalog.

F. Stipend and Support Information

Students may be eligible for financial support if they are properly enrolled for graduate studies and are in good academic standing. When questions arise regarding stipend or fellowship information, students should consult with their advisor or the Admin in 222 McNutt.

Students may be supported through a research assistantship, which is the most common type of support in our department. These assistantships are also referred to as a stipend. The stipend can be for a 25% or 50% appointment. For a 50% appointment, a minimum of 20 hours of effort per week toward the research project is required. This does not include time necessary to fulfil work related to research credit hours or thesis. Thus, the time commitment per week will be significantly greater. Students funded through research contracts may expect to carry out research that goes beyond their thesis or dissertation research, though their dissertation research in many cases will be related to the contract that sponsors them.

Students may also be supported through fellowships sponsored by organizations such as the National Science Foundation, NASA, and the U.S. Department of Education. Most of these fellowships are based on merits.

There is no defined vacation policy for supported students. Absence away from the laboratory is typically agreed upon by the student and the advisor. Students are reminded that they are here to pursue their education and that extended absences will ultimately delay

their graduation date, which may also impact the ability of the advisor to maintain financial support for the student. Students are also reminded that the typical vacation policy of most companies is that new employees receive only two weeks of vacation (10 days per year) plus standard holidays during the first five years of employment. Holidays would include New Year's Day, Martin Luther King Day, Memorial Day, July Fourth, Labor Day, Thanksgiving Day, and Christmas. It is also common for most companies to not grant any vacation, other than holidays, to employees with less than 1 year of service. Whether a student is compensated (paid) while on vacation is at the discretion of the advisor.

G. Instructional Education Policy

In the required MSE 5000 graduate course, students will participate in scholarly tasks to give them useful experience in undergraduate instruction and research. All MSE, MET and CER MS students are required to enroll for one semester (one credit hour) of MSE 5000 as part of their program of study. PhD students must enroll for two semesters of MSE 5000 (one credit hour each semester), and these two semesters should not be consecutive. Credit for MSE 5000 can be applied to the total credit hours required for both the MS and PhD programs of study. Enrollment in MSE 5000 should be coordinated with the MSE Associate Chair for Graduate Programs and the student's advisor. It is recommended that the MSE 5000 requirement be completed as early during the program of study as practical. For MS students, this will typically mean the 5000 assignment will be completed during the first three semesters, and for PhD students completing two assignments, that both assignments will be completed during the first six semesters of study.

H. Lab Cleanliness

Lab cleanliness is part of a good lab hygiene approach to maintain a safe working environment. We must all do our part to ensure our safety, the safety of those around us, and the safety of the environment. **Hazardous materials need to be disposed of properly and we should always clean up our work area when we are finished (DO NOT leave the chemicals that are finished with around for someone else to clean up. Call for chemical pickup through Environmental Health (see MSE Safety Manual).** Leaving chemicals or samples lying around is not acceptable practice. It's also not fair to the next person who will work in the area.

Students are encouraged to plan ahead for their experiments to make sure all necessary supplies are on hand prior to initiation of the experiment. They are also encouraged to develop their common sense when it comes to working in the laboratory. For example, it is unfortunately too common to see colleagues walking around the building with plastic gloves on that they have been wearing in a laboratory as part of the personal protective equipment to minimize their exposure to a potentially hazardous reagent touching a door knob to open a door. When you see someone do this, you might ask them what they just deposited on the door for all the rest of us to touch. Also, please do not track sand and/or dust through the hallways.

You should read the attached safety manual, and if you are working with potentially toxic chemicals, you are encouraged to review the book Prudent Practices for Handling Hazardous Chemicals in Laboratories by The Committee on Hazardous Substance in the Laboratory, National Research Council (National Academy Press, Washington D.C., 1991).

As mentioned above, safe practices start with maintaining a clean work area. Frequently, some of us are left cleaning up after others, because they either were in a hurry or didn't care. This is very unfair to your peers and your colleagues in the lab. You might find the article below by Coach John Wooden interesting. I hope you will take the time to read it. For his line of work, cleaning up when you were done was simply common courtesy. For us, it is both common courtesy and a good safety practice.

Comments from John Wooden, Coach of the 10-time NCAA Champion UCLA Basketball Team, "Orange Peels, Pride and Productivity"

"I frequently received letters from custodians after we played an away game telling me our basketball team had left the locker room neater and cleaner than anyone who visited during the year. The towels were put in bins, soap was picked up off the shower floor, and so forth.

The locker rooms were clean when we departed because I asked the players to pick up after themselves. I believe this is just common courtesy. Somebody's going to have to clean it up, and I see no reason why it shouldn't be the person who messed it up. Are managers and custodian's the players' servants?

In basketball we often have orange slices or gum at the half. I see no reason why you should throw those orange peels or gum wrappers carelessly on the floor. There are receptacles for that. Again, it's just common courtesy.

As with many of the rules that I had, there are other less obvious but equally important reasons for insisting on them. In this case, it goes to the image of the team, both our self image and the image others have of us."

Excepted from Wooden, A Lifetime of Observations and Reflections On and Off the Court, John Wooden and Steve Jamison (Contemporary Books, New York, 1997).

I. Seminar Policy

Seminars serve as an effective way to broaden technical expertise in a reasonably concise time period and may thus contribute to the professional development of students. Seminars also provide an opportunity for networking for both faculty and students, and represent one of the few opportunities where the department meets as an entity on a regular basis. Seminar will meet each Thursday at 3:30 pm in McNutt 204 during each week of the fall and winter semesters. Each seminar will be preceded by a reception for the speaker at 3:00 pm in the McNutt commons. These times are subject to change for special seminars. The semester seminar schedule is posted online at: Department Seminars – Materials Science and Engineering | Missouri S&T (mst.edu). Seminar speakers will be invited by the faculty within the department and will include a range of technical topics spanning materials science, ceramics, biomaterials, metallurgy, professional development, and global issues as they relate to materials and engineering. Suggestions from graduate students for potential seminar speakers are welcomed.

Seminar attendance is required of all graduate students during their residency on campus and attendance sheets will be distributed during seminar. All MSE, MET and CER MS (thesis based) and PhD students must enroll for seminar (MSE 5010) once during their residency on campus.

When registering for this course, students should enroll for 1.0 credit hours. For all graduate students enrolled in MSE 5010, seminar will be graded on a S/US basis. ***As indicated in the syllabus, the seminar grade will be based on attendance, participation, and the quality of the presentation given by the student during the semester in which he/she is enrolled.*** All graduate students are required to give a presentation during the semester in which they are enrolled.

J. Purchasing Policy

1. Check with your advisor before completing forms to ensure they will authorize the purchase. Be sure the forms are filled out as completely as possible. Please ensure that detailed descriptions of the required goods are included, along with appropriate part numbers. The forms are located in McNutt 220.
2. If you need to make a purchase from a local company, please see the department staff **BEFORE** making the purchase. There is a student credit card available for use with prior approval from your advisor. **If you do not follow this procedure, you may not be reimbursed for a purchase made with personal funds as all purchases must be approved PRIOR to the expense.**
3. When using a departmental credit card, items to be purchased must be pre-approved on the purchase authorization form. If the item is not listed on the authorization form, it cannot be purchased.
4. ***If you need to return anything you ordered, or there is a problem with the order, let the purchasing staff handle it; DO NOT call the company yourself***. The purchasing staff needs to document all returns/resolutions to problems on the order forms. Staff will not be responsible for errors in the return process if the student does not follow this policy.

K. Keys

You will send an email to your advisor requesting the rooms you need access to. You will then send an email to the owners of each room requesting access to the rooms please include office staff in all emails. For access to the building, you can use your ID card on the card swipe located at the handicap entrance. The keys take approximately two weeks from the order date. If the keys are returned when leaving Missouri S&T, you will be issued a refund for the deposit(s). If the keys are lost, it must be reported to the department as soon as possible, and the deposit is forfeited. You will be charged a $100.00 non-refundable fee for replacement keys and/or a hold placed on your student records. ***If you leave campus without turning in your keys, your student account will be charged $100 per key***. **DO NOT loan your keys to someone else…they are YOUR responsibility!!**

L. Gas Cylinders

There is a form to order gas cylinders located in room 220 McNutt Hall. PLEASE NOTE: Gas cylinders must be always chained down in the labs and should not be moved through the hallways without the proper cart.

EHS Policy states the following: *When you obtain gas from distributors, make sure you arrange to have the vendor pick up the empty cylinders. Avoid purchasing lecture bottles - their disposal is extremely expensive. When you receive a new product, notify your AMR and they will get it into the inventory. The bar-code will be attached to a removable tag. When you exchange the cylinder for a new one, you may transfer the tag ONLY if the size and contents are identical. If a contractor exchanges cylinders, make sure they know to exchange the tags. If you receive a new gas or a different sized container, it will need a new bar-code.*
In other words, gas cylinders are to be treated like any other chemical as regards Chemtrack, the exception being that you may transfer the barcode tags, as explained above. We do recommend that *you* exchange the barcode tags removed from the empty cylinders to the full ones, and not count on the vendors to do this. So please treat the tracking of gas cylinders like any other chemical and notify us of any change in your cylinder (or chemical) inventory.

M. Building Security

It is necessary to lock all laboratories in McNutt, Fulton and MRC, particularly late in the afternoon during the week and on weekends. Students entering or leaving a laboratory should secure any doors that were, or should be locked, as appropriate. **DO NOT prop doors open.**

N. Technical Society Memberships

Membership in technical societies can greatly assist the career development of students. All students are strongly encouraged to join and actively participate in the above technical societies, both at the department and national levels. In addition, student membership fees in these organizations are quite reasonable. Membership forms may be found at the appropriate websites.

O. Laboratory Safety Course Information

Note: Also see Section I.A – Introductory Information

The Environmental Health & Safety Department at Missouri S&T offers a number of optional and required safety courses. It is recommended that students visit the departmental web site at http://ehs.mst.edu to view a complete list of services provided by this organization. This site contains information on the Chemical Inventory System, Material Safety Data Sheets (MSDS), the Environmental Management System, the Hazardous Waste Management System, and other safety information.

Required safety training includes:

- Laboratory Safety Training for Graduate Students (including Environmental Management System Awareness). This is an on-line training and you will have to be signed up by Graduate Admin in order to complete this.

In addition to the above required safety training, the Environmental Health & Safety Department also offers courses on “Chemtrack Computer Training” and “Chemical Storage Hazards.” Chemtrack will help with SDS information, awareness of waste management requirements and inventory control by increasing inventory accuracy, reducing purchasing costs, reducing shipping costs, and reducing potential disposal costs. Students who work

extensively with chemicals and hazardous materials are strongly encouraged to complete these courses.

P. Checkout/Departure Procedures

1. Notify the Graduate administrative staff in 222 McNutt of the date of your departure from Missouri S&T.
2. Check and clean up any leftover chemicals/samples in lab. If chemicals/samples need to be reassigned to another person, notify (in writing) the staff in 222 McNutt. Have your advisor "sign off" on form located on page 18 stating this has been completed and turn this form into the Graduate Studies administrative staff (Room 222).
3. If you have gas cylinders assigned to you, please follow step #3.
4. Turn in lab notebooks to your advisor as appropriate.
5. Return keys to the staff in 222 McNutt.
6. Make sure the department and your advisor has a copy of your thesis/dissertation.

Form on page 18 must be signed by advisor and submitted to Graduate administrative staff in room 222 McNutt prior to leaving campus.

II. Degree Requirements

A. General Information

Below is an abbreviated description of the basic degree requirements for graduate degrees offered by the MSE department. The complete Missouri S&T graduate requirements can be located at http://registrar.mst.edu/cataloginfo/cataloginfo/. These requirements must be read and understood by all graduate students.

All graduate forms Graduate Student Forms – Graduate Education | Missouri S&T (mst.edu) **Please note that all deadlines must be observed**.

If the semester graduate GPA falls below 3.0 the student will be placed on probation for the following semester. If the graduate GPA is not 3.0 or above in the following semester that coursework is taken, the student shall no longer be a candidate for a graduate degree or certificate from Missouri S&T.

B. M.S. with Thesis

Degree Requirements

Students working toward their M.S. with Thesis degree are required to take a minimum of 30 credit hours. Credit hour and other degree requirements include:

1. A minimum of 18 credit hours of 4000, 5000 or 6000 level lectures, with a minimum of 6 credit hours of 6000-level lectures (Special Problems does not count).
2. A minimum of 6 credit hours of MSE, MET or CER 6099 (Research).
3. The student must enroll in MSE 6120 (Thermodynamics and Phase Equilibria)
4. The student's Advisory Committee will consist of the **advisor and at least two other committee members**.
5. Students must enroll once for 1 credit hour of MSE 5000 (Special Problems). Further information can be found in section I-G (Instructional Education Policy). On the program of study form, credit for MSE 5000 should be indicated under the category for "Research 6099, Special Problems (4000/5000/6000), Seminar (5010)."
6. Students are required to enroll for 1.0 credit hours of seminar (MSE 5010) once as part of their program of study. On the program of study, credit for seminar should be indicated under the category "Research 6099, Special Problems (4000/5000/6000), Seminar (5010)."
7. All graduate forms must be submitted online (as posted on the website for the Graduate Studies Office) so they can be checked for committee members and have time to be processed. It is your responsibility to follow this requirement.

Recommendations for Program of Study

1. While not required, it is recommended that all M.S. students enroll in MSE 6110 (Bonding, Crystallography, and Structure-Property Relations), and MSE 6130 (Kinetic Theory for Materials).
2. There is no requirement related to 3000 number courses. However, a maximum of 6 credit hours of 3000-level lecture courses may be accepted into the MS with Thesis program of study with the advisor's approval.

Thesis Requirement and Oral Examination

The findings and results of research undertaken by the candidate must be presented in a thesis. All theses are prepared following the specifications given in the manual entitled "Specifications for Thesis and Dissertations (T/D)" which is available at the following web site: https://grad.mst.edu/studentservices/thesisdissertationguide/, unless a different format is approved in advance. Note that the MSE Department requires literature review in the thesis.

The student will distribute copies of the thesis to the examining committee (his/her thesis advisory committee) and arrange a time and place for the oral defense of the thesis. Each committee member should be allowed a minimum of one week (two weeks suggested) to examine the thesis prior to the scheduled date of the oral defense. The defense may be comprehensive in character and the candidate should exhibit an acceptable knowledge of a professional area as defined by the program.

Students are required to coordinate the announcement of their defense date and time with the MSE Graduate administrative staff (room 222) so that all faculty may have the opportunity to attend the defense (Note: The VPGS office will notify the Registrar's Office to either retain or delete your name from the commencement list). **This must be done a minimum of one week (preferably two weeks) prior to the scheduled defense date. If not given a minimum of one week notice of defense, you will NOT be allowed to defend! No defense can be scheduled on Thursday afternoons when a regular departmental seminar is being presented!**

For more effective use of the committee, in addition to the thesis and oral examinations, the candidate is encouraged to:

- Submit a written description of the proposed research to the members of the committee as soon as the topic is decided,
- Obtain written approval of the committee indicating that the proposed research is of M.S. caliber, and
- Submit periodic progress reports to the committee and discuss them with the committee members or with the committee as a group.

The student is strongly encouraged to review the Graduate Catalog for additional information regarding the requirements and conditions of the M.S. program.

C. Master's Degree without Thesis

Degree Requirements

Students working toward their non-thesis M.S. degree are required to take a minimum of 30 credit hours. Credit hour and other degree requirements include:

1. A minimum of 9 credit hours of lecture courses bearing numbers in the 6000 series.
2. All students must enroll in MSE 6120 (Thermodynamics and Phase Equilibria) and MSE 6130 (Kinetic Theory for Materials).
3. Complete at least 18 credit hours in the MSE department.
4. Complete at least 18 credit hours of 6xxx and 5xxx lecture courses combined.
5. Must complete grad form 1 or 1-A

Recommendations for Program of Study

1. It is recommended that at least six semester hours will be devoted to courses outside the major department.
2. While not required, it is recommended that all M.S. students enroll in MSE 6110 (Bonding, Crystallography, and Structure-Property Relations).
3. There is no requirement related to 3000 number courses. However, a maximum of 6 credit hours of 3000-level lecture courses may be accepted into the MS without Thesis program of study with the advisor's approval.

The student is strongly encouraged to review the Graduate Catalog for additional information regarding the requirements and conditions of the M.S. non-thesis program.

D. Ph.D. Requirements

Degree Requirements

Students working toward their Ph.D. degree are required to take a minimum of 72 credit hours. Specific credit hour requirements for the Ph.D. degree are indicated below.

Students with master's degree:

For those students who have received a master's degree from Missouri S&T or other institution, the requirement can be met by completing 42 hours beyond the master's degree, as a block of 30 hours can be transferred from the master's degree.

- Twelve credit hours must be the four core graduate courses, including MSE 6110 (Bonding, Crystallography, and Structure-Property Relations), MSE 6120 (Thermodynamics and Phase Equilibria), MSE 6130 (Kinetic Theory for Materials), and MSE 6140 (Communication in Materials Science and Engineering).
- Twenty-four credit hours of graduate research (5099/6099) is required.
- A maximum of 6 credit hours of 3000-level lecture courses may be accepted into the PhD program of study with the advisor's approval.
- 3000-level and non-lecture (e.g., special problems (5000/6000) or seminar (5010/6010)) courses only count toward the total credit hour requirement and do NOT count toward the lecture or research credit hour requirements.

Students without master's degree:

- Requires a minimum of seventy-two hours of graduate credit.
- Thirty credit hours must be 4000-, 5000-, and 6000-level lecture courses. Recommended that fifteen credit hours of the required coursework come from the group of 6000- level lecture courses. Twelve credit hours must be the four core graduate courses, including MSE 6110 (Bonding, Crystallography, and Structure-Property Relations), MSE 6120 (Thermodynamics and Phase Equilibria), MSE 6130 (Kinetic Theory for Materials), and MSE 6140 (Communication in Materials Science and Engineering).
- Thirty credit hours of graduate research (5099/6099) is required.
- A maximum of 6 credit hours of 3000-level lecture courses may be accepted into the PhD program of study with the advisor's approval.
- 3000-level and non-lecture (e.g., special problems (5000/6000) or seminar (5010/6010)) courses only count toward the total credit hour requirement and do NOT count toward the lecture or research credit hour requirements.

Other degree requirements for the Ph.D. degree for ALL students include:

1. All Ph.D. students must pass the qualifying exam by the end of the fifth semester of their Ph.D. program. Details of the qualifying exam are discussed in the section below.
2. Students must take and pass a comprehensive examination. The examination must be scheduled and passed a minimum of 12 weeks prior to the dissertation defense examination. The examination may not be scheduled prior to completion of at least 75% of the student's lecture coursework.
3. Each student is required to serve as a Graduate Teaching Assistant (GTA) in two semesters. In each of the two semesters, they must enroll for 1 credit hour of MSE 5000 (Special Problems). On the program of study form, credit for MSE 5000 should be indicated under the category for "Research (6099), Special Problems

(4000/5000/6000), Seminar (5010)."

4. Students are required to enroll for 1.0 credit hour of graduate seminar (MSE 5010) once as part of their program of study. On the program of study, credit for seminar should be indicated under the category "Research (6099), Special Problems (4000/5000/6000), Seminar (5010)."
5. All graduate forms must be turned in to the Graduate administrative staff (room 222) a minimum of 48 hours before their deadlines (as posted on the website for the Graduate Studies Office) so they can be checked for committee members and have time to be processed It is your responsibility to follow this requirement or the form may not make the deadline for the semester.

Qualifying Examination Format

The Ph.D. Qualifying Examination serves as an early screening tool to determine if the student has the necessary technical background and intellectual aptitude to pursue the Ph.D. Those students who possess correctable deficiencies in their technical backgrounds will be informed and appropriate corrective actions suggested. Those who lack the necessary background or aptitude for doctoral level study will not be allowed to continue in the Ph.D. program.

The MSE Associate Chair for Graduate Programs and for Research will be responsible for administering the Qualifying Examination. The Qualifying Examination must be passed by the end of the fifth semester of enrollment in the Ph.D. program. The oral examination is offered twice each year, in mid-August and in mid-January, on the Friday before the first week of the Fall or Spring semester.

A pre-requisite to take the Ph.D. Qualifying Examination is obtaining an A or B in each of the four required 6000-level core classes, or if a grade lower than B is obtained, with an exception from the Associate Chair of Research. One of these 6000 level courses is a writing intensive course entitled "MSE 6140: Communication in Materials Science and Engineering" that all PhD candidates are required to take. This course is typically taught every Fall. The other three 6000-level courses are: MSE 6110 (Bonding, Crystallography, and Structure-Property Relations; or "Crystallography"); MSE 6120 (Thermodynamics and Phase Equilibria); and MSE 6130 (Kinetic Theory for Materials).

The Ph.D. Qualifying Examination consists of three components: a written research proposal; an oral presentation; and oral defense of the proposal. The student must submit an acceptable written proposal developed within the "MSE 6140: Communications in Materials Science and Engineering" course, two weeks in advance of the oral examination date, to the Associate Chair for Research. The oral presentation will last for 10 minutes, with 10 slides allowed; the slides must be submitted to the Associate Chair for Research one day before the oral examination date.

For each student, the Ph.D. Qualifying Examination is conducted by a committee of three faculty members (not to include the student's advisor) assigned by the Associate Chair for Research; the committee for each student is different, with members familiar or unfamiliar with the student's research area. After the 10-minute oral presentation, the student must defend the proposal to the committee in around 40 minutes. The committee deliberates and makes a decision in ~10 minutes. The three committee members score a grading rubric. 8 rubric criteria are graded on a satisfactory (S) or unsatisfactory (U) basis based on the consensus and majority rule of the three committee members.

The Ph.D. Qualifying Examination evaluation procedure is as follows:

1. The committee members will score the rubric.
2. The ACR will tally the grades from the committee members. For each grading criterion, the majority rule applies.
3. Depending on the result of the tally, there are 3 possible outcomes:
   1) Pass –8 S, 0 U out of the 8 grading criteria
   2) Conditional pass – 6-7 S, ≤2 U out of the 8 grading criteria
      - The committee will identify deficiency and remedial action, with input from the advisor as appropriate. A conditional passing grade will require the student to complete a remediation assignment to overcome the deficiencies identified during the qualifying exam.
      - At the end of the semester, the remediation assignment will be reviewed by the same qualifying exam committee. If the qualifying exam committee finds the submitted remediation work acceptable, with input from the advisor, then the student will pass the MSE PhD Qualifying Exam. The remediation assignment must be completed by the end of the semester immediately following the Qualifying Exam. If the remediation assignment is not acceptable or submitted, then the student will receive a Fail grade.
   3) Fail – ≤5 S, ≥ 3 U out of the 8 grading criteria

If the student receives a Fail grade, they may retake the exam. However, a passing grade must be obtained by the end of their fifth semester of the PhD program to continue in the PhD program. Otherwise, the student will not be allowed to continue in the MSE PhD program.

As the Qualifying Examination provides an opportunity to evaluate a given student's ability to perform at a satisfactory level, the advisor is expected to provide guidance but should refrain from the following:

- Reviewing and editing the written proposal
- Reviewing and editing the presentation slides

The grading rubric that the Qualifying Examination committee will use is indicated below. Students are encouraged to carefully review and think about the rubric well before the exam.

Ph.D. Qualifier Rubric

	U	S
Knowledge: An ability to apply knowledge of subject matter within their field of study		
Literature Review and Contextualization *Effectively situates the research within existing literature, identifying relevant gaps or opportunities. References are up-to-date and appropriately cited.*		
Understanding of Core Concepts *Demonstrates a clear understanding of fundamental theories, principles, and methodologies relevant to the field. Accurately applies them in the proposal and provides accurate and precise answers.*		
Communication: An ability to communicate effectively within their field of study		
Articulation of Hypotheses and Objectives		

Hypotheses are specific and testable. Research objectives are well-defined, measurable, and aligned with the proposed methodology.		
Clarity of Communication *Oral and written presentations and responses to questions are clear, concise, logical, and supported with appropriate data or references. Figures, tables, or diagrams are well-designed, labeled, and enhance understanding.*		
Structure and Formatting *Proposal and presentation adhere to guidelines, with a logical flow, proper headings, proper citations, and consistent formatting.*		
Critical Thinking: An ability to engage in productive critical thinking within field of study		
Originality and Innovation *Demonstrates project originality and shows potential to advance knowledge. Research questions or methods are innovative.*		
Feasibility and Rigor *Research plan is well thought out, with feasible goals, realistic timelines, and appropriate methodologies. Potential challenges are identified and addressed. Contingency plans are provided.*		
Reasoning and Application *Thoughtfully engages with complex or unexpected questions, providing logical, well-reasoned, and creative responses. Recognizes and acknowledges limitations in the research or identifies areas for further exploration when appropriate.*		

Comprehensive Examination

The Comprehensive Examination (i.e., the Preliminary Examination), taken after completion of at least 75% of a student's lecture coursework (**must be a minimum of 12 weeks prior to defense of dissertation**), consists of a written proposal and an oral presentation. The written proposal should include a detailed project plan/timeline to graduation and the sections described below. The examination will be administered by the dissertation advisory committee of the candidate. The written proposal is to be distributed to the advisory committee two weeks prior to the oral presentation date, which may be scheduled at any time throughout the year by the committee chair. **Notice of the comprehensive examination shall be given to the Graduate administrative staff (room 222) at least two weeks prior to the examination so the faculty and students in the department can be notified.** Any faculty member within the department may attend the Comprehensive Examination of any student, but only the dissertation advisory committee will vote on whether the students passes or fails the Comprehensive.

The principal objective of the Comprehensive Examination is to obtain additional evidence regarding mastery of both the major field of study and the specific area of specialization. A "Pass" or "Fail" of the Comprehensive Examination will be based on a unanimous (or unanimous minus one) vote of the advisory committee. Other aspects governing the dates and requirements of the Comprehensive Examination are reported in the Graduate Catalog under Admissions and Program Procedures.

The written proposal portion of the Comprehensive Examination should not exceed 7000

words. The following format for the proposal is strongly suggested:

(1) Cover Page (Proposal Title, etc.)
(2) Research Objective
(3) Background Information (abbreviated literature review; 5 – 8 pages)
(4) Preliminary Results (5 – 10 pages)
(5) Proposed Work and Timeline (5 pages) – includes details of experiments planned, models to be completed, and analyses to be performed
(6) Comments on Special Needs (materials, supplies, equipment, etc.)
(7) Impact of Work – highlight the contributions of the work to the current understanding in the field (1 page)
(8) References
(9) Curriculum Vitae

Dissertation and Final Examination

The dissertation, embodying the results of an original investigation, must be written upon a subject approved by the major advisor. The dissertation should be prepared following the specifications given in the manual entitled "Specifications for Thesis and Dissertations (T/D)" which is available at the following web site: Thesis and Dissertation Guide – Graduate Education | Missouri S&T (mst.edu). Note that the MSE Department requires literature review in the dissertation. The advisory committee shall examine the dissertation closely for both scientific content and format, and deem it worthy of acceptance by the graduate faculty as meeting the requirements for the doctor of philosophy degree. It may not be scheduled sooner than 12 weeks after the completion of the comprehensive examination. **You will need to submit a "Final Doctoral Defense Notification Form" (located at: https://grad.mst.edu/studentservices/navigatingyourdegreeprogram/forms/doctoral/) at least 2 weeks prior to the exam to the Grad Studies Office. Notice of the final examination (dissertation defense) shall also be given to the Graduate administrative staff (room 222) at least two weeks prior to the examination so that the faculty and students in the department can be notified. No defense will be allowed to take place if notice is less than 2 weeks! No defense can be scheduled so that it would overlap with the Department's afternoon seminars (held on Thursdays of each week).** The final examination will be an oral defense of the dissertation and may be attended by any interested person, who may question the candidate with permission of the chair of the advisory committee. A student who fails the final defense a second time will no longer be eligible to receive a doctoral degree from that program. However, the student is still eligible to pursue a doctoral degree from any other graduate degree program willing to accept them.

The student is strongly encouraged to review the Graduate Catalog for additional information regarding the requirements and conditions of the Ph.D. program.

E. Checklists and Deadlines

M.S. with Thesis Checklist and Deadlines

Requirement	Due Date/Deadline	Date Completed
1. Select advisor and committee and complete Form 1* Master's Degree Forms – Graduate Education | Missouri S&T	The program of study is due during the semester a student will have completed nine hours of graduate credit.	
2. Completes academic requirements (see above)	No deadline but should be within four semesters.	
3. Students must make application for diploma (online at: http://registrar.mst.edu/forms/	Within four weeks of the beginning of the final semester.	
4. Candidate distributes copies of the thesis to examination committee.	At least 14 days before the final defense.	
5. Arrange a date, time, and place for the oral defense of the thesis. (The student must be enrolled at the time of the defense.)	Examination must be scheduled to meet university graduation deadlines.	
Notify the Graduate administrative staff (room 222) **minimum 2 weeks** in advance of date/time and place of defense.	Email date/time/place/title/advisor to Michelle Mbchh@mst.edu	
6. Submit original of Grad Form 2 to the Graduate admin staff in 222 McNutt.	To meet university deadlines.	
7. Submit approved copy of thesis to VPGS Office (G8 Centennial Hall).	To meet university deadlines.	

Non-Thesis M.S. Checklist and Deadlines

Requirement	Due Date	Date Completed
1. Student registers after consultation with advisor	Pre-registration period	
2. Student and MSE Associate Chair for Graduate Programs identifies advisor.		
3. Complete Grad Form 1* Master's Degree Forms – Graduate Education | Missouri S&T	The program of study is due during the semester a student will have completed nine hours of graduate credit.	
4. Completes academic requirements.	No deadline, but should be within four semesters.	
5. Students must make application for diploma (online at: http://registrar.mst.edu/forms/	Within four weeks of the beginning of graduating semester.	

* Students who fail to comply with the deadline for submission of Form 1 will have a registration hold placed on their records by the VPGS office.

Ph.D. Checklist and Deadlines

Requirement	Due Date	Date Completed
1. Completes admission requirements.	Prior to enrollment.	
2. Pass qualifying examination.	Prior to the end of the fifth semester.	
3. Graduate Form 4 (Qualifying Exam) completed. Doctoral Degree Forms – Graduate Education | Missouri S&T	The qualifying examination must be passed no later than the end of the fifth semester of enrollment in a doctoral program. Enrollment on the date of examination is required.	
4. Student consults with advisor to select an appropriate advisory committee of five members.	As soon as possible after qualifying examination is completed, but in no instance more than six weeks after passing the qualifying examination.	
5. Prepare the plan of study and complete Grad Form 5. Doctoral Degree Forms – Graduate Education | Missouri S&T		
6. After the candidate has completed at least 75% of the coursework required for the doctoral degree, as listed on their approved plan of study, the advisory committee may administer the comprehensive examination. Enrollment on the date of examination is required. A candidate will be considered to have passed the examination if all, or all but one, of the advisory committee members recommend that the candidate pass.	Doctoral Degree Forms – Graduate Education | Missouri S&T	
7. Maintain continuous enrollment in accordance with Policy Memo II-20, until degree is completed or candidacy is cancelled.		
8. Students must check with the registrar to make application for diploma. http://registrar.mst.edu/forms/	Within four weeks of the beginning of the final semester.	
10. Dissertation distributed to advisory committee.	At least 14 days prior to the date of the defense.	
11. Student and advisor select date, time and location of final examination and inform the Graduate admin staff (room 222) electronically so that final examination can be publicly announced. Email date/time/place/title/advisor and attach abstract to mbchh@mst.edu	At least 14 days prior to the intended defense date and in accordance with other university semester deadlines governing graduation. **If department is not informed a minimum of 2 weeks prior, the defense will not be allowed to take place!**	
12. Complete and submit Grad Form 7 accompanied by approved copy of the dissertation.	To meet university deadlines.	

Checkout Procedure Form

1. Notify the Graduate administrative staff in 222 McNutt of the date of your departure from Missouri S&T.
2. Check and clean up any leftover chemicals/samples in lab. If chemicals/samples need to be reassigned to another person, notify (in writing) the staff in 222 McNutt. Have your advisor "sign off" below stating this has been completed and turn this form into the Graduate administrative staff.
3. If you have gas cylinders assigned to you, please follow step #3.
4. Turn in lab notebooks to your advisor as appropriate.
5. Clean out your desk, file cabinets, etc that you used so the next person does not have to clean up after you.
6. Return keys to the staff in 222 McNutt.

I certify that _____ has properly disposed of all chemicals and samples. If chemicals/samples need to be reassigned to another person, notify (in writing) the staff in 222 McNutt. Have your advisor sign below stating these steps has been completed and turn this form into the Graduate administrative staff.

Other comments:

_____ _____

Advisor's Signature Date

Appendix A

Safety Manual

Lab Safety Program ToC – Environmental Health and Safety | Missouri S&T (mst.edu)

Appendix B

Graduate Forms

All graduate forms are now available online:
Graduate Student Forms – Graduate Education | Missouri S&T (mst.edu)

Please note that when filling out graduate forms 1 (M.S.) and 5 (Ph.D.) they MUST match your transcript exactly. Make sure your degree program name is correct (do not use the department "name" as your degree program).

If you are making a course correction only on your Program of Study (i.e., MS-Grad form 1A or PhD-Grad Form 5A), the only signatures needed are yours and your advisor's (do not need the entire committee to sign every time).

Appendix C

Articles Regarding Plagiarism and Fraud

Ohio U. Says 37 Former Graduate Students Committed Plagiarism and Could Face a Range of Penalties

By THOMAS BARTLETT

An investigation at Ohio University has found that 37 former graduate students in engineering plagiarized portions of their theses or dissertations, though what punishments they will face remains undecided.

A committee formed to look into the allegations, which were brought to light by a former graduate student, issued a report on Friday saying that all but seven of the 44 former students investigated had committed significant plagiarism. The committee recommended that the plagiarists be given the chance to rewrite the portions in question. It also found no evidence of research misconduct, i.e., proof that the results of experiments had been fabricated.

The university, in Athens, Ohio, declined to release the names of the former students.

The recommendations struck Dennis Irwin, dean of the Russ College of Engineering and Technology, as too lenient. "I'm reserving the right to take more strict penalties," Mr. Irwin said.

Those penalties could include adding a notation to the transcripts of the former students saying that they had committed plagiarism. Punishments might also include revoking degrees. Mr. Irwin said there remains a chance that the professors who advised students guilty of plagiarism will face repercussions.

The graduate student who discovered the widespread plagiarism, Thomas A. Matrka, also thought the committee was too lenient. "The focus needs to be as much on the faculty as it is on the students," said Mr. Matrka.

Mr. Matrka said he also believed that there were, in fact, instances of research misconduct. "I know of an example where a student copied parts of his discussion of results of an experiment," he said.

Most of those guilty of plagiarism were international students, according to Mr. Irwin. They have nine months to respond in writing to the charges. If they fail to do so, he said, their degrees will be revoked. The university has yet to contact most of the former students.

Fraud Shows Peer-Review Flaws

By Eric Lerner

The peer-review system is supposed to guarantee that published research is carried out in accordance with established scientific standards. Yet recently, an internal report from Lucent Technologies' Bell Laboratories concluded that data in 16 published papers authored by researcher Hendrik Schön were fraudulent. The papers were reviewed and accepted by several prestigious scientific journals, including *Nature*, *Science*, *Physical Review*, and *Applied Physics Letters*. Yet, in many of the papers, the fraud was obvious, even to an untrained eye, with data repeated point-for-point and impossibly smooth or noise-free. All the papers passed through internal review at Bell Labs, one of the world's foremost industrial research institutions, and the journal peer review system without raising alarms. The fraud was discovered only after journal readers started pointing it out.

What went wrong? Does the Schön affair indicate major flaws in the peer-review system? In its aftermath, many people are asking these questions, and some are suggesting reforms. The implications may extend beyond the relatively limited problem of preventing scientific fraud to the broader question of ensuring the fairness and efficacy of peer review itself.

On September 24, 2002, a Bell Labs committee of inquiry chaired by Malcolm R. Beasley, professor of applied physics and of electrical engineering at Stanford University, concluded that Schön had committed scientific misconduct by manipulating and misrepresenting data, substituting mathematical functions for data, and creating false data. Bell Labs immediately dismissed Schön, which ended a career of apparently extraordinary productivity. From 1998 to 2002, Schön authored or co-authored no fewer than 100 papers, an average of one every other week. These were no ordinary papers but claimed significant advances in a variety of fields—organic semiconductors, organic superconductors, inorganic superconductors, and fullerenes. Schön's productivity peaked in mid-2001, when he submitted several papers only a few days apart. In a period of 10 weeks, from late September to early December, Schön published 12 papers. Many of them, although not all, were co-authored by Bertram Batlogg, a senior Bell Labs researcher with a long record of accomplishment.

Yet in case after case, efforts to duplicate the results failed. By late 2001, researchers were pointing to obvious discrepancies in Schön's data. In response, Bell Labs convened its inquiry committee in May 2002, which concluded that in paper after paper, data had been duplicated, with the same data ascribed to different experiments. In the most glaring cases, in a paper published in *Science* (2000, 289, 599) and another in *Nature* (2001, 410, 189), Schön presented the same data in the same paper as coming from different experiments. In addition, other data were in reality mathematical functions or were impossibly perfect, varying from theoretical predictions by less than a tenth of a standard deviation. When confronted with these accusations, Schön admitted some substitutions but insisted he had done the experiments. However, he kept no systematic logbooks, and he claimed that the raw data had all been erased because of a lack of computer storage space.

Bell Labs' failure

Clearly, the first defense of the integrity of scientific results (other than researchers' own morality) lies in the collaboration of co-authors and colleagues and in the review of the procedures of a research laboratory. At Bell Labs, these defenses failed for several reasons. First, although Schön had co-authors on all of his papers, in actuality "all device fabrication, physical measurement, and data processing … were carried out by Hendrik Schön alone…. None of the most significant physical results was witnessed by any co-author or colleague," the Bell Labs' report concluded.

"In our view, this was an isolated, anomalous incident," says Saswato Das, a spokesman for Bell Labs. "Many of the experiments in question were done when Schön was in Germany working at the University of Konstanz, waiting for his visa, so it was not possible for colleagues to participate in those experiments." However, many of the fraudulent papers, including one of the more egregious cases of copying data within a paper, were submitted for publication in 2000. At that time, Schön was working continuously at Bell Labs' main facility in Murray Hill, New Jersey, in a laboratory only steps away from Batlogg's office. According to Das, Schön met frequently with collaborators Christian Kloc and Batlogg. Yet at no point did either man look at the raw data or ask to participate in one of Schön's claimed experiments.

"This is certainly not the way things used to be at Bell Labs," says John M. Rowell, a former director of chemical physics at Bell Labs who worked there from 1961 to 1983. "In the good old days, experiments would be immediately witnessed by one or sometimes even two levels of management, and by collaborators."

Nor did the collaborators or anyone else question Schön's spectacular productivity until late 2001, when he was asked to slow down and focus on the details. "Actually, Schön was only among the top four in productivity at Bell Labs that year, so it was not considered that strange," says Das. "Everyone knew he practically lived at Bell Labs and was there at all hours."

But others find this attitude incredible. "It is clearly impossible to make an experimental device—especially for the first time—take measurements, and write a paper every four or five days," comments Rowell. "If three others at Lucent were submitting more than one paper each week as well, a committee probably should look at their papers, too. The collaborators and management had a responsibility to demand more proof of such unbelievable productivity."

Lucent Technologies, the parent of Bell Labs, has laid off 88,000 workers in the past two years, and as a result, Bell Labs has suffered significant cutbacks. Did this contraction of personnel make it more likely that scientists would work alone on experiments, instead of in pairs or teams, and that collaborators, pressed for time, would give only cursory review to even spectacular results? Would the need to maintain output with fewer researchers give management an incentive to praise extraordinary output rather than see it as a warning flag? Das does not think so. "People at Bell Labs have always worked in about the same manner. As we are smaller today than in the past, we have reduced the number of areas of focus," he asserts. Thus, research groups are not necessarily smaller than before the cutbacks.

But again, Rowell and others disagree, noting recent changes at Bell Labs, whatever the cause. "Years ago, not only were research teams larger than one person, and first-line

supervisors expected to be handson researchers, there was a rigorous publication release process that involved circulation of papers to management and other researchers, " says Rowell. "Evidently, that's not functioning anymore."

Peer-review breakdown

Once the papers were submitted for publication, how did they get past so many sets of reviewers? Clearly, it was not the fault of one or two reviewers because of the many articles involved. Nor did editors ignore warnings from the reviewers. "After the story broke, we looked back over the reviewer reports," says Monica Bradford, managing editor of *Science*, "but we did not find any clues that something was wrong." Although it is common for journal reviewers to critically comment on a paper's data and raise questions about noise levels and statistics, not one reviewer at any journal caught the fact that the data was impossibly good or copied from chart to chart.

Some in the scientific community think that the reviewers should not be blamed for missing the flaws in Schön's papers. "Referees cannot determine if data is falsified, nor are they expected to," argues Marc H. Brodsky, executive director of the American Institute of Physics, which publishes *Applied Physics Letters*. "That job belongs to the author's institution, and the readers if they deem the results are important enough. A referee's job is to see if the work is described well enough to be understood, that enough data is presented to document the authors' points, that the results are physically plausible, and that enough information is given to try to reproduce the results if there is interest."

But editors at leading journals take a broader view, and they admit that the reviewers were among those at fault. "Clearly, reviewers were less critical of the papers than they should have been, in part because the papers came from Batlogg, who had an excellent track record, and from Bell Labs, which has always done good work," admits Karl Ziemelis, physical sciences editor at *Nature*. "In addition, although the results were spectacular, they were in keeping with the expectations of the community. If they had not been, or had they come from a completely unknown research group, they might have gotten closer scrutiny." Thus, reviewers and editors as a group had a bias toward expected results from established researchers that blinded them to the problems in the data.

The Schön case points to problems in the peer-review system on which considerable discussion has focused recently, and which affect aspects of science far more significant than the infrequent case of fraud. "There is absolutely no doubt that papers and grant proposals from established groups and high-prestige institutions get less severe review than they should," comments Howard K. Birnbaum, former director of the Frederick Seitz Materials Research Laboratory of the University of Illinois at Urbana-Champaign. He recently criticized peer-review practices in grant awards in an article in *Physics Today*. It is not just a problem of fraud, he says. I and colleagues have seen sheer nonsense published in journals such as *Physical Review Letters*, papers with gaping methodological flaws from prestige institutions.

Because journals have a limited number of pages and government agencies have limited funds for research, too lenient reviews of the established and the orthodox can mean too severe reviews of relatively unknown scientists or novel ideas. The unorthodox can be frozen out, not only from the most visible publications but also from research

funding. Not only does less-than-sound work get circulated, but also important, if maverick, work does not get done at all. The peer-review system's biases, highlighted in the Schon case, tend to enforce a herd instinct among scientists and impede the self- correcting nature of science. This is scarcely a new problem. As Samuel Pierpont Langley, president of the American Association for the Advancement of Science, wrote in 1889, the scientific community sometimes acts as a pack of hounds...where the louder-voiced bring many to follow them nearly as often in a wrong path as in a right one, where the entire pack even has been known to move off bodily on a false scent.

Fixing the system

A number of reforms being discussed could reduce the publication of fraudulent or unsound work and make room for better research. Science is already considering implementing one of the less drastic steps. requiring that raw data accompany experimental or observational articles and that the data be posted as supplementary material on *Science*'s Web site. Such a step would make simple fraud more detectable and would enable others to use the same data for alternative interpretations.

Another idea is to have every experimental paper reviewed by a statistician, says Ann Weller, an expert on peer review and associate professor of library sciences at the University of Illinois at Chicago. Such a statistical review would presumably have flagged several of Schon's papers, and would cut back on dubious statistical analysis, a common flaw of many papers.

Bell Labs has introduced one change in procedure. It now requires the posting of all papers for seven days on a prepublication archive before submission to a journal, which allows colleagues to participate in a review process. However, given the ease with which digital data can be fabricated. in ways that are harder to catch than Schon's were.there seems to be no substitute for collaborations in which more than one researcher participates in experiments or at least looks at the raw data. Such collaborations can also lead to higher-quality research and problem solving.

One way to encourage real collaborations rather than passive co-authoring is to have the responsibility of co-authors listed in the published paper -- for example, device fabrication by John Doe, experimental procedure by Jane Smith, data analysis by Tom Harold. Senior researchers would then have to take co-responsibility for specific aspects of an experiment, or remove their names from papers to which they contributed little.

None of these changes, however, directly addresses the bias of reviewers toward prestigious groups and accepted ideas. More drastic reforms aim at fundamental changes in the system of anonymous review. Blind review, for example, involves removing the authors' names from articles sent to reviewers, while open review requires reviewers to sign their names to reviews seen by authors.

"Blind review can potentially eliminate biases about authors, but only if the reviewer cannot guess who the author is from the references", explains Weller. "Studies have shown that in about 40% of papers, the reviewer can guess the authors." On the other hand, blind review does not address biases against novel ideas.

Open review reduces the possibility of bias, argue supporters such as Fiona Godlee, editorial director for medicine at Biomed Central, an online publishing company in London. If authors know reviewers' names, reviewers must take personal responsibility for their reviews, and authors can see if editors have chosen reviewers in a balanced manner. If reviewers are also publicly known and their reviews available, editors or funding agencies presumably would not assign papers or proposals from high-prestige groups to reviewers likely to withhold criticism. Authors could also object if only supporters of the mainstream approach review a minority viewpoint.

It is difficult to say in advance whether open review would incline reviewers to be more conscientious about catching fraudulent or sloppy work. So far, no major physical-sciences journal or funding agency has adopted such a radical reform. However, the idea has received sufficient support for *The British Medical Journal* to allow open review of some papers.

Online discussion

Some researchers wonder whether peer-reviewed journals are essential and whether some of their functions could be replaced by online discussion. "If online prepublication archives, such as arXiv, allowed chatroom-style comments on each paper and author's replies, the community at large would make its own decisions as to the validity of the results", suggests Rowell. "My bet is that such a chat room for the Schon papers would have been overwhelmed by critical comments because I heard plenty of them informally, but they were not published."

Whatever reforms eventually emerge, the Schon case has highlighted the need for peer-review improvements, and a vigorous discussion of how to change is timely. After my article in *Physics Today*, I got a hundred e-mails of support, but almost all of them told me not to mention their names, comments Birnbaum. Now, such underground criticism of peer review may come out into the open.