Ethics in physics: The need for culture change

A new American Physical Society survey shows that although ethics education is more prevalent than it was nearly two decades ago, unethical research practices and harassment are still significant problems in the physics community.

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In 2002 two highly publicized events shattered the common complacent view that the quantitative nature of physics research and strong peer-review practices would shelter the discipline from ethics violations. The first, at Lawrence Berkeley National Laboratory, was the retraction of Victor Ninov's claimed discovery of two new elements[1] (atomic numbers 116 and 118). The other, at Lucent Bell Labs, was mounting suspicions about Jan Hendrik Schön's false data showing extraordinary properties of many novel materials, including high-temperature superconductors and thin films for device applications. (See *Physics Today*, November 2002, page 15.) Investigations at both institutions uncovered flagrant data fabrication. Those events showed that ethical practice in physics could not be taken for granted and added to a growing awareness that ethical practice in scientific research was not a given.

The American Physical Society's Panel on Public Affairs (POPA), which in 2002 had the primary responsibility for ethical matters,

commissioned a task force charged with understanding how physicists are taught about ethics and with making recommendations for further actions APS could take to address ethical concerns. The task force—on which two of this article's authors (Kirby and Houle) served—surveyed physicists at diverse career stages in 2003. The most informative survey was of what were then called junior members, which roughly corresponds to today's APS Early Career members. Those physicists had acquired their PhDs three years or less before the survey and could speak to their experiences as students, postdocs, and newly independent researchers. They were asked how they learned about ethical practices and what their experiences were with ethics issues in their research training. That survey found a distressing rate of unethical research practices and a lack of formal ethics training, as described in an article from two of us (Kirby and Houle) on page 42 of the November 2004 issue of *Physics Today*.

In 2020 a follow-up survey was sent out to two APS member cohorts, early-career scientists and graduate students, to investigate whether ethics awareness and practice had improved since the original survey. The data show that although ethics education improved over the 17 years—addressing what a 2003 respondent called "the silence that exists now"—serious challenges remain. The push to do flashy science and publish numerous papers creates pressure to cut ethical corners. Early-career physicists and graduate students also continue to report mistreatment and abuse. Drawing from the responses, the APS Ethics Committee has formulated recommendations for consideration by the APS leadership, which are given at the end of this article.

Original surveys

In the 2003 surveys, unethical practices were narrowly defined according to the still-current Federal Policy on Research Misconduct, explained in box 1. The definition includes fabrication of data, falsification of research processes or misrepresentation of the research record, and plagiarism, often shortened to fabrication, falsification, and plagiarism (FFP). The FFP definition establishes a minimum standard for acceptable behavior and does not imply that all other behaviors are acceptable. For example, it does not encompass criminal behavior, conflicts of commitment, violations of grant-management policies, or other unacceptable behaviors not unique to research, such as discrimination and harassment.

The original APS survey focused on FFP and the best practices for preventing that behavior, such as maintaining an accurate research record and properly citing the literature. Nearly 50% of APS junior members responded—most within hours of receiving the web-based survey. That remarkable response rate suggested the topic hit a nerve with the group. The responses revealed that ethics were not routinely taught in any part of the educational environment, including laboratory and lecture courses and research groups. Moreover, open-ended responses revealed a shocking level of abuse of students and postdocs, including harassment, threats, and expectations of overwork.

As a result of those findings, APS issued a statement on respectful treatment of subordinates and launched a Task Force on Ethics Education to create a set of case studies specific to physics as a resource for active education about research ethics. (The library of case studies is now linked to the Ethics Program webpage of APS’s website.) The Task Force on Ethics Education also recommended

establishing a standing committee on ethics in APS, but that recommendation was not adopted at the time. The then editor-in-chief of *Physical Review*, Martin Blume, brought together an international consortium of scientific journal editors that led to the formation of the Committee on Publication Ethics. It has put in place many standards and processes for journals to ensure the integrity of the research record. Those standards impact how papers are submitted for publication, how journals evaluate the integrity of those manuscripts, and how concerns about specific papers are managed.

After 2003, ethics-focused activities in APS went into a quiet period, aside from the work of the Task Force on Ethics Education. Other organizations, however, continued to work on ethics education. As part of the America COMPETES Act in 2007, NSF was and still is required to ensure that any institution applying for research funds provides appropriate training in responsible and ethical conduct of research for students and postdocs. American Geophysical Union (AGU) members raised issues about how people were treated in the field and pointed to the impacts of harassment on the scientific enterprise. In response, AGU created a code of conduct for its meetings and issued the comprehensive 2017 document *AGU Scientific Integrity and Professional Ethics*, which expanded scientific misconduct beyond FFP to include mistreating people. That same year, the National Academies of Sciences, Engineering, and Medicine issued the report *Fostering Integrity in Research* to address concerns that a lack of focus on ethics, including research misconduct and detrimental research practices, places the systems that fund and train young scientists at risk.

In 2017 one of us (Kirby) became the CEO of APS and another of us (Houle) the chair of POPA, which is responsible for the oversight of ethics and for APS's policy statements. We realized that scientific misconduct occurred across all disciplines, in part because of the high-pressure and competitive research climate. (For an overview of ethics surveys across fields, see box 2.) Additionally, people who are considered outsiders, such as underrepresented individuals, or powerless, such as students, were often subject to abuse. POPA saw that the existing APS ethics policies needed to be updated and that a new approach was needed to communicate ethics expectations beyond a series of short, disconnected statements.

After considerable work by a group of POPA members and external experts, completed when another one of us (Marder) was POPA chair, APS adopted a unified comprehensive set of Guidelines on Ethics, part of which is shown in box 3. The lengthy document covers many aspects of ethics, including core topics addressed in earlier statements, such as FFP, conflicts of interest and commitment, treatment of subordinates, and authorship. It also adds elements, such as the Code of Conduct for APS Meetings, guidance on the appropriate use of research funds, and sections that raise harassment and bias to the level of ethical violations. At the same time, POPA recommended and the APS Council approved the establishment of a committee on ethics.

The Ethics Committee (EC) started its work in 2019. Among many initial activities, the EC proposed processes to ensure that ethical conduct is considered when nominating physicists for awards and elected positions in APS and to revoke honors or appointments of

individuals who had been found by institutional investigations to have committed violations called out in the APS Guidelines on Ethics. The EC also recognized the importance of measuring physicists' awareness of ethics to compare with the 2003 findings. With oversight from the EC, APS worked closely with the American Institute of Physics's Statistical Research Center to craft, conduct, and analyze the 2020 survey. (The American Institute of Physics is the publisher of *Physics Today*.)

Then and now

We (Houle, Kirby, and Marder) and the other members of the EC wanted to know how the physics ethical landscape had evolved since the 2003 survey. The EC thus repeated many of the same questions word for word in the 2020 survey. The 2003 survey went to all APS junior members, and 748 responded. The 2020 survey received 1390 responses from APS members within five years of their PhD, the most similar current APS membership cohort. In 2003 and 2020, the EC received thousands of responses to open-ended questions. As part of the analysis of the 2020 survey, the committee grouped those responses into categories and selected representative quotes.

As shown in figure 1a, around the same percentage of early-career APS members had read the previous APS ethics statements in the 2003 survey as had read the current guidelines in the 2020 survey. But in 2020 far more of those surveyed knew about the policies for misconduct at their institutions. In 2003 only 22% had read their institutional policies for misconduct, whereas in 2020 the percentage rose to 71%.

In 2003, 61% of early-career APS members said they had never had formal ethics training, but by 2020 that percentage dropped below 5%.

In both surveys, group meetings with research supervisors were the most common training setting; see figure 1b. The 2020 respondents were somewhat less likely to have discussed ethics informally and somewhat more likely to have discussed the issues in coursework.

In the earlier survey, 7.7% of the early-career APS members said they had at some point felt pressure to violate professional ethical standards. In 2020, that percentage significantly increased to 12.5%. In open-ended responses, the 2020 early-career members described the factors that led them to consider ethical violations: pressure from supervisors, pressure to publish, pressure to acquire funding, pressure to get a high citation count, and pressure to obtain significant results even if data must be manipulated. Here are some representative anonymous responses:

> *“[There is a] declining quality of publications due to senseless publication pressure. In my opinion, the number of publications should be in no way an indicator for the scientific standing of e.g. an applicant. What is better: One revolutionary, mind-blowing paper, o[r] a large number of meaningless papers? Often only the number of publications is important.”*
>
> *“Supervisors and funders demand results and don’t appreciate that ethical and thorough research takes time.”*
>
> *“My advisor was unethical and pressured me to do unethical things. I resisted and was punished by him for it.”*

By contrast the percentage who observed or had personal knowledge of ethical violations showed a significant drop from 39% in 2003 to

26% in 2020. Enthusiasm for that progress must be tempered, however, when specific violations are examined in more detail.

The respondents could select from an identical list of ethical violations in 2003 and 2020. Although a smaller percentage of 2020 respondents reported seeing any violations at all, those who reported violations reported more of them. The net result is that many violation categories show no significant change between 2003 and 2020.

The two most serious ethics violations that affect the research record are plagiarism and data falsification. The incidence of plagiarism remained about the same as in 2003, as shown in figure 2. Data falsification, on the other hand, increased from 3.9% of respondents reporting witnessing it in the earlier survey to 7.3% in 2020. The result is consistent with the increased pressure to commit ethical violations that early-career members reported. For example, some respondents said:

> *“I felt as if I wouldn’t survive in the environment that I was in if I didn’t ‘go with the flow.’ ”*
>
> *“We wouldn’t fake data, but we would sometimes omit data for impact reasons or shove it deep in the supplementary. For example, one measurement or two measurements that show good agreement with our hypothesis would go into the main manuscript, and any subsequent ones that were noisier or ‘weird’ would go to supplementary or be left out.”*

There was a modest although significant decrease in the incidence of some more minor infractions: putting nonauthors on a paper, omitting a student’s name from a paper, and failing to cite relevant literature.

Harassment

The 2020 survey included information from 2829 graduate students, a group not included in the 2003 survey. The most noteworthy differences between graduate students and early-career members are that graduate students were significantly less likely to report having seen ethical violations—19% versus 26%—and significantly less likely to report pressure to violate ethical standards—9% versus 13%. That difference may be because the early-career members have been in the field longer and have greater awareness. Alternatively, it may be because those who continue in a research career feel pressure to succeed more acutely and are thus more likely to speak up. Another possibility is that the graduate students may not feel confident or empowered enough to protest even in an anonymous survey. One respondent said:

> *"For us coming from humble backgrounds standing up against injustice is incredibly hard for the fear of losing our educational degrees. It would be extremely nice if APS monitor[ed] physics departments in the Universities to keep an eye out for unjustified unethical behavior towards minority/women."*

The new survey also included questions on harassment that had not been posed in 2003. To those questions overall, there were 3577 responses from graduate students and early-career APS members, of whom 795 identified as women, 2348 identified as men, 37 identified as neither women nor men, and 397 preferred not to identify gender.

The differences between the experiences of men and women are striking, as shown in figure 3. Women are five times as likely as men are to feel that they were treated differently, ignored, or put down

because of their group affiliation and to have heard comments of a sexual nature or tone. Around 15% of the female respondents reported being touched without permission compared with 2% of male respondents. The written comments even included multiple reports of rape by coworkers. Respondents with gender identities other than male or female gave responses between those of men and women.

People who have been treated badly may be more likely to respond to surveys. But the 70 early-career women who reported physical harassment constitute 8.3% of all female early-career APS members. That prevalence is unacceptable even if none of the nonrespondents have been harassed.

A question about whether the respondent had reported inappropriate behavior and whether they were satisfied with the institutional response elicited more than 900 open-ended responses. The majority (740) said they did not report the harassment. For example, one respondent wrote:

> *“As it happened to me, I chose not to mention it. I was also about to graduate and didn’t want anything to delay that.”*

Of the 190 respondents who said they reported the behavior, only 61 said they were satisfied with the institutional response. There were 93 respondents who said they made reports but were unsatisfied, and 97 who said they feared retaliation. One respondent said:

> *“I and several others reported the sexual harassment. I was extremely unhappy with the institutional response. The institution moved very slowly and made the person who was harassed*

> *repeat her story many times over to many different people reopening the wound constantly."*

Interpersonal interactions

The early-career physicists of 2003 are today's midcareer scientists. Although today's early-career scientists are more aware of responsible research conduct and ethical practices in general, the experiences of physicists at all career levels have not changed significantly. The physics community still needs to deal with serious ethical issues.

One of the last questions on the survey asked what the respondents thought were the most serious professional ethics issues that should be addressed by APS. Of the total 1199 responses, interpersonal ethics issues—such as discrimination, harassment, and abuse of power—were listed twice as often (60% of responses) as professional practice issues (30%). One respondent wrote:

> *"I have not witnessed unethical practices in data collection/reporting. I have witnessed unethical personal interactions."*

Among those professional ethics topics, 17% of respondents deemed data manipulation the most serious, but the pressure to publish, the review process, and citation and authorship each garnered 4–5% of responses. Here are some representative responses about the potential role of APS in addressing such ethical issues:

> "*The APS has the greatest authority to speak on issues of scientific ethics."*

> *“I think APS is in a strong position to set the tone for professional conduct in the physics community at large.”*

> *“I think there is not only a concerning lack of diversity in physics, but a culture that reinforces the homogeneity through biased comments and attitudes. Addressing these is the most important ethics issue I think APS should deal with.”*

Discrimination, harassment, and abuse of power often stem from and flourish in the unequal power dynamics in academia, which can become toxic when advisers, principal investigators, or other authority figures are themselves under pressure to publish. As one respondent said:

> *“The advisor has complete control over the student’s future, so preventing that inherently unequal power dynamic from becoming a major problem is absolutely paramount.”*

Respondents noted that toxic dynamics give rise to increased stress, mental health problems, and unsustainable work–life balance for students and postdocs. Numerous studies have found that individuals part of one or several underrepresented groups—such as women and people of color—experience more toxic behavior than, for example, white men.[2] One survey respondent said:

> *“Everyone I know who is not a cisgendered heterosexual white man [and] who has left the field has left because of how they were treated, not because they didn’t want to be a physicist.”*

As in the 2003 survey, many 2020 early-career scientists said that the pressure to publish research results quickly and in high-impact journals leads to a decline in the quality of papers, careless or shoddy handling

of data, and other ethical concerns. Many respondents made accusations of blatant data falsification and manipulation:

> "*Distorted data and interpretations are widespread. These are not obvious violation[s] of professional ethics but can cause harm and waste to other researchers [that] trust the publications. Grad students, and researchers in general, should receive a formal course in data collecting and reporting practice.*"
>
> *"However, instances of data-falsification, plagiarism, unnecessary inclusions of authors on papers, etc. are either directly due to or at least encouraged and exacerbated by the highly competitive environment of science/academia."*

The responses show that early-career scientists have a strong desire for APS to address interpersonal interactions as well as the ethics involved in professional practice. Doing so is a significant challenge for the organization and will involve establishing and helping to enforce new behavioral norms in the physics community.

Recommendations

With the concerns of students and early-career physicists in mind, the APS Ethics Committee formulated a number of recommendations for consideration by APS leadership.

1. Develop educational materials

Although ethics education has improved at the university level over the past two decades—driven in part by NSF requirements for responsible and ethical conduct of research and Title IX compliance—the survey results cast doubt on its effect. That minimal influence may be because

of the nature of most formal institutional ethics training: largely web based, without detailed discussions of situations, and lacking opportunities for questions. APS should develop new materials that are relevant to physics and effective.

2. Foster more respectful behavior

Changing the physics culture to embrace respectful treatment of others as a core value could help reduce instances of harassment, discrimination, and toxic power dynamics.[3] Much work remains to reduce the pressures that have fueled and enabled such behavior. A new initiative, the APS Inclusion, Diversity, and Equity Alliance, helps physics departments and laboratories to share and implement strategies for improving diversity, equity, and inclusion and thus decrease instances of harassment and discrimination. The goal is a more respectful, welcoming, and inclusive community. The Effective Practices for Physics Programs guide, which was created in a collaboration between APS and the American Association of Physics Teachers, also provides practices and strategies to improve physics-department culture in many areas, including ethics.[4]

3. Identify new ways to assess researchers

The San Francisco Declaration on Research Assessment[5] and the Leiden Manifesto[6] are important initiatives in the social science and biology communities that promote moving beyond simplistic metrics, such as journal impact factors or *h*-indexes, to evaluate the quality of scientific work. APS should consider following suit and establishing a task force to develop ideas for assessing physics research quality that can guide hiring and tenure or promotion review at research institutions.

4. Highlight accountability

To demonstrate that the APS Guidelines on Ethics are taken seriously, APS should find ways to highlight when its policy for revocation of honors has been implemented and an honor has been revoked. APS should also promote structural best practices that reduce the absolute power that an individual research adviser has over the careers of graduate students and postdocs. For example, rather than relying solely on the opinion of the adviser, a departmental committee could meet once a year or more to assess a student's progress, identify problems and roadblocks, and help ensure timely completion of the PhD.

5. Expand the concerned community

In an increasingly interdisciplinary scientific world, changing the physics culture and advancing ethical best practices can only be accomplished by working with other scientific and engineering societies. APS leadership should reach out to other science-based organizations and explore mutual interests, activities, and potential opportunities.

The authors are grateful to the many people involved in this project, especially Jeanette Russo for her work on the survey, Jim Heath for categorizing all open-ended responses according to emergent themes, the members of the Ethics Committee from 2019 to today, and the APS leadership for their comments and support. We thank the respondents to the surveys for their time and thoughtful comments, which are tremendously helpful to APS and the physics profession.

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Figure captions

Figure 1**. Survey responses** from early-career American Physical Society members in 2003 and 2020 show how their awareness of ethics statements and guidelines have changed.

Figure 2. Ethics training has become more common in 2020 than it was in 2003 according to the responses from early-career American Physical Society members.

Figure 3. Ethical violations across a range of categories were observed by different percentages of early-career American Physical

Society members in 2003 and 2020. Notably, although many categories show no significant changes, the rates of data falsification nearly doubled in 2020 compared with 2003.

Figure 4. Harassment is a common experience, particularly for women, as reported by graduate students and early-career American Physical Society members in 2020. The 397 respondents who left the question about their gender blank are not included.

Boxes

Box 1. Research misconduct

The Office of Science and Technology Policy defines “research misconduct” as “fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results.”[7]

► Fabrication is making up data or results and recording or reporting them.

► Falsification is manipulating research materials, equipment, or processes or changing or omitting data or results such that the research is not accurately represented in the research record.

► Plagiarism is the appropriation of another person’s ideas, processes, results, or words without giving appropriate credit.

The office’s research misconduct policy also sets the legal threshold for charges of misconduct. To be considered research misconduct, actions must represent a “significant departure from accepted practices,” be “committed intentionally, or knowingly, or recklessly,” and be “proven by a preponderance of evidence.” [7]

Box 2. Ethics surveys

The 2003 American Physical Society survey was the first to examine ethics in practice in physics and among the first to examine ethics in any of the physical sciences. Since then important surveys of physics and other disciplines have been published and revealed nuances in how the scientific enterprise works. The frequency of misconduct is somewhat lower in the physical sciences than in biological, medical, and social sciences, but the patterns and types of misconduct are similar. Those patterns help pinpoint where significant improvements in ethics education and practice are needed in all sciences.

Reports examined ethics in medical physics,[8] sexual harassment experienced by female undergraduate physics majors and how that negatively affects their persistence in STEM (science, technology, engineering, and mathematics) fields,[9] the scope of National Institutes of Health–funded scientists' misconduct beyond fabrication, falsification, and plagiarism,[10] and research practices across disciplines in the Netherlands.[11] The Dutch survey, for example, showed that half the respondents admitted to questionable research practices and that about 4% said they had fabricated or falsified data in the preceding three years. The findings in those publications are consistent with those of the American Physical Society surveys in 2020 and 2003.

Box 3. APS Guidelines on Ethics

The American Physical Society Guidelines on Ethics rest on the principles given in its preamble (https://www.aps.org/policy/statements/19_1.cfm): "As citizens of the global community of science, physicists share responsibility for its welfare. The success of the scientific enterprise rests upon two ethical

pillars. The first of them is the obligation to tell the truth, which includes avoiding fabrication, falsification, and plagiarism. The second is the obligation to treat people well, which prohibits abuse of power, encourages fair and respectful relationships with colleagues, subordinates, and students, and eschews bias, whether implicit or explicit. Professional integrity in the conception, conduct, and communication of physics activities reflects not only on the reputations of individual physicists and their organizations, but also on the image and credibility of the physics profession in the eyes of scientific colleagues, government, and the public. Physicists must adopt high standards of ethical behavior, and transmit improving practices with enthusiasm to future generations.”