Women Physicists Speak: The 2001 International Study of Women in Physics

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ABSTRACT

Abstract. The Working Group on Women in Physics of the International Union of Pure and Applied Physics (IUPAP) subcontracted with the Statistical Research Center of the American Institute of Physics (AIP) to conduct an international study on women in physics. This study had two parts. First, we conducted a benchmarking study to identify reliable sources and collect data on the representation of women in physics in as many IUPAP member countries as possible. Second, we conducted an international survey of individual women physicists. The survey addressed issues related to both education and employment. On the education side, we asked about experiences and critical incidents from secondary school through the highest degree earned. On the employment side, we asked about how the respondents' careers had evolved and their self-assessment of how well their careers had progressed. In addition, the questionnaire also addressed issues that cut across education and employment, such as the impact of marriage and children, the factors that contributed the most toward the success they had achieved to date, and suggestions for what could be done to improve the situation of women physicists.

HIGHLIGHTS

- The report contains country-level data and anecdotal information about the representation of women in physics from 34 countries.
- Most of the women physicists who responded to this survey reported that they developed an interest in physics during or before they were in secondary school. This emphasizes the importance of the opportunity to study physics and the encouragement to pursue science early in the academic system.
- Respondents felt they had generally positive experiences as undergraduates and as graduate students.
- About one-third of the women who responded felt that they had progressed more slowly in their careers than their colleagues had.
- The demands of a career in physics seemed to preclude several of the women in our study from marrying or having children. Of those who are married, a significant number reported that marriage affected their work. When comparing themselves to their colleagues, women with children were more likely than women who do not have children to say their careers had progressed slowly.
- The factor most frequently cited by women physicists as contributing to their success was the support of their families, including their parents and husbands. Many also mentioned the support of advisors, professors, and teachers, and some cited the support of colleagues. Also frequently mentioned were the women's own determination, will power, and hard work.
- Barriers that the women mentioned included the problems of balancing the demands of child care with the demands of a scientific career. Another barrier was discriminatory attitudes, usually expressed in the form of assumptions that women cannot do physics.
- Three out of four women who responded said that they would choose physics again.

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SECTION I: COUNTRY-LEVEL DATA AND ANECDOTAL INFORMATION

This section contains country-level data and anecdotal information on the representation of women in physics from various countries.

Country-Level Data

The country-level data (Table 1) were compiled from external, reliable sources such as government agencies and physics societies that routinely collect data such as these. In order to be included in the country-level data, countries had to provide accurate numbers of physics graduates broken down by year, level of degree, and gender.

TABLE 1. Percentages of Physics Degrees Awarded to Women in Selected Countries, 1997 and 1998 (2-year averages).

Country	Ph.D.'s %	First-Level %
France	27	33
Poland[a]	23	36
Norway[b]	23	20
Ukraine[c]	23	—
Australia[d]	22	20
Turkey	21	37
India[e]	20	32
Columbia[f]	—	28
Denmark	17	19
Lithuania[g]	17	—
United Kingdom	16	20
China-Taipei	13	19
United States	13	18
Sweden	13	17
Canada	12	22
Mexico[h]	10	18
Germany[i]	9	10
Switzerland[j]	9	9
The Netherlands	9	5
South Korea	8	30
Japan	8	13

[a] Poland: 1998 data only.
[b] Norway: 1996-2001 data.
[c] Ukraine: 2000-2001 data.
[d] Australia: Ph.D. data include some master's degrees (higher degree by research).
[e] India: Partial data from the Registrar General of India, 1998.
[f] Columbia: 1998 and 1999 data.
[g] Lithuania: 1996-2001 data.
[h] Mexico: Ph.D. data for 1998 only. Bachelor's data for 1998 and 1999.
[i] Germany: Includes astronomy and astrophysics.
[j] Switzerland: 1999-2000 data.

Anecdotal Information

The anecdotal information was collected mainly through personal correspondences of the IUPAP team leaders with universities and colleges in their countries. Although some team leaders were able to obtain fairly complete information, it was not appropriately broken down by year, and so could not be included in the comparison of country-level data. A complete list of sources is at the end of the report.

Albania

First-Level Degrees

- The three institutions that award first-level degrees for a teacher of physics reported awarding 16 degrees to women and 13 degrees to men during the 1999-2000 school year.

Armenia

First-Level Degrees

- The one institution that grants first-level degrees reported awarding 30 degrees to women and 35 to men during an unspecified time period.

Ph.D. Degrees

- The six institutions that award Ph.D. degrees reported awarding one degree to a woman and three to men during an unspecified time period.

Cameroon

First-Level Degrees

- The University of Dschang reported awarding 24 degrees to women and 131 to men since 1993.

Chile

First-Level Degrees

- The Pontificia Universidad Catolica de Chile reported awarding 10 degrees to women and 81 to men since 1978.
- The Universidad de Santiago de Chile reported awarding eight degrees to women and 55 to men from 1990 to 2000.

Ph.D. Degrees

- The six institutions that grant Ph.D.'s in physics reported awarding six degrees to women and 54 to men since 1975.

China-Beijing

- The Chinese Physical Society reported that 15% of its members are women.

Columbia

Ph.D. Degrees

- The four institutions that grant Ph.D.'s in physics reported awarding one to a woman and five to men during an unspecified time period.

Croatia

First-Level Degrees

- One of the four institutions that grant first-level degrees reported awarding approximately 10 degrees to women and 20 to men during an unspecified time period.

Ph.D. Degrees

- The two institutions that award Ph.D. degrees reported awarding approximately one degree to a woman and four to men during an unspecified time period.

Czech Republic

Ph.D. Degrees

- During an unspecified period of time, five Ph.D. degrees were awarded to women and 30 were awarded to men.

Estonia

First-Level Degrees

- Two of the three institutions that grant first-level degrees reported awarding 16 degrees to women and 60 to men between 1999 and 2001.

Ph.D. Degrees

- One of the two institutions that grant Ph.D. degrees reported awarding one degree to a woman and 12 to men between 1999 and 2001.

Iran

First-Level Degrees

- 46 of the approximately 66 institutions that grant first-level degrees reported awarding 200 degrees to women and 350 to men during an unspecified time period.

Ph.D. Degrees

- Nine of the 12 institutions that grant Ph.D. degrees reported awarding three degrees to women and 25 to men during an unspecified time period.

Israel

Ph.D. Degrees

- At Tel Aviv University there were 12 Ph.D. degrees awarded to women and 53 awarded to men from 1998 to 2001.

Lithuania

First-Level Degrees

- The five institutions that grant first-level degrees reported awarding 84 degrees to women and 184 to men during 2000 and 2001.

South Africa

First-Level Degrees

- The University of Potchefstroom reported awarding six first-level degrees to women and 61 to men over the last 10 years.

Ph.D. Degrees

- The University of Port Elizabeth reported awarding one Ph.D. to a woman and five to men between 1991 and 1995.
- The University of Potchefstroom reported awarding two Ph.D.'s to women and 12 to men over the last 10 years.
- The University of Cape Town reported awarding one Ph.D. to a woman and four to men over the last five years.

Sudan

First-Level Degrees

- Three of six institutions that grant first-level degrees reported awarding 56 degrees to women and 97 to men during an unspecified time period.

Federal Republic of Yugoslavia

First-Level Degrees

- Five of the six institutions that award first-level degrees reported awarding 561 degrees to women and 525 to men over the last 15 years.

Ph.D. Degrees

- The four institutions that grant Ph.D.'s reported awarding 76 degrees to women and 266 to men since 1947.

SECTION II: THE INTERNATIONAL SURVEY OF WOMEN IN PHYSICS

How the Survey Was Conducted

There is no source for the names and contact information for all physicists (irrespective of gender) in every country. Thus, we relied on personal networks among women physicists in each IUPAP country. The team leaders in each country were asked to e-mail women physicists they knew in their countries. The latter were asked to complete the questionnaire and return it via e-mail to the Statistical Research Center, as well as to forward the questionnaire to other women physicists they knew. During the summer and early fall of 2001, Dr. Marcia Barbosa, chair of the Working Group, e-mailed team leaders in IUPAP countries on several occasions to encourage them to disseminate the questionnaire. We eventually received more than 1000 responses from women physicists in more than 50 countries. Table 2 shows the number of responses by country.

TABLE 2. Number of Women Physicists who Responded to the International Study by Country, 2001.

Continent/Country	Number	Continent/Country	Number
Africa		**Europe**	
Cameroon	2	Albania	6
Egypt	13	Armenia	8
Nigeria	20	Austria	4
South Africa	23	Belarus	2
Tanzania	1	Belgium	26
Zimbabwe	2	Bulgaria	3
Asia		Croatia	13
China-Beijing	27	Czech Republic	5
China-Taipei	5	Denmark	17
India	42	Estonia	5
Indonesia	16	Finland	1
Israel	9	France	37
Japan	57	Germany	30
Malaysia	1	Greece	2
Pakistan	2	Ireland	72
South Korea	21	Italy	41
Turkey	73	Latvia	13
Uzbekistan	1	Lithuania	2
Australia/New Zealand		Netherlands	22
Australia	16	Norway	1
New Zealand	1	Poland	4
North America		Portugal	1
Canada	48	Romania	5
Cuba	6	Russia	24
Mexico	9	Spain	21
USA	82	Sweden	12
South America		Switzerland	17
Argentina	27	UK	47
Brazil	33	Ukraine	3
		Yugoslavia	20

The authors worked with the IUPAP Working Group on Women in Physics to develop several versions of the questionnaire instrument. In light of the unique character of the educational and economic systems in each country, we decided to focus on a few key issues and a few key stages in the education and careers of physicists. It was decided that to attempt a more detailed picture would have required a questionnaire of considerable length, which would have been an enormous burden on the respondents. Even so, the final questionnaire instrument grew to six pages in length.

The findings from the international survey include women physicists who responded even if they do not currently live in an IUPAP country. However, the report on this study does not include responses either from men physicists or from those women whose highest degrees were in fields other than physics.

Cautionary Comments

Readers of this report are cautioned about the generalizability of the data from the survey. First, although we heard from women physicists who currently reside in more than 50 countries, their experiences may not be representative of all women physicists in all countries. In fact, the personal networks that made it possible to contact women physicists may also bias the results in favor of those women who are known and reachable by e-mail. Thus, in some countries, the women who responded may overrepresent the number of women physicists who are academically employed. Also, e-mail was used almost exclusively in the distribution of the questionnaire. However, e-mail is not yet universally available, and so some women physicists may not have had the opportunity to participate in the study.

Second, the study only includes those women physicists who persisted. Students who dropped out of physics during their education could not be identified. Had we been able to include such students, we may have received more negative comments about the educational systems in different countries. We were unable to locate women physicists who left physics after earning an advanced degree. Thus, the survey did not have adequate representation from women physicists who could not find jobs in physics, those who left physics because they had children and were expected to devote their time to their families, or those who left physics because of discriminatory attitudes. Finally, the survey did not include women who did not have the opportunity to pursue advanced education because of the economic, social, political, or educational systems in their countries.

Finally, the questionnaire instrument was written in English, and some women physicists are not fluent in English. Thus, some questions may have been misunderstood. Also, we saw evidence in the replies to open-ended questions that some respondents were having difficulty expressing themselves using English.

Encouragement From Parents

Most of the women physicists who responded to this survey reported that they developed an interest in physics during or before they were in secondary school (Table 3). Thus, early encouragement to pursue education and an early exposure to science are fundamentally important, and family members are in an excellent position to provide these experiences.

Parents play an essential role in the development of their children. They can encourage their children to pursue education and to pursue science. They can provide their children with hands-on scientific experiences and can expose children to exciting scientific events going on around them. Parents also play an essential role in the development of a child's self-esteem. This strong belief in one's intellectual ability is a critical source of strength

TABLE 3. When Did You First Think of Choosing Physics as a Career?

	Percent[a]
Before high school	13
During high school	58
During first-level degree	24
During graduate degree	4

[a] Percents do not sum to 100 due to rounding.

during the rigors of physics education. Confidence in one's ability can be especially important for female students when they confront the negative effects of sexism, which can cause women to question their ability or their right to pursue advanced degrees.

"My parents always expected a lot from me and gave the required support. I learned very early to believe in myself. I have also met professors with a lot of prejudice against women, but as I had a sound self-esteem, it did not really harm me." [Brazil]

"My dad always encouraged me in mathematics and science and was never too busy to answer questions and foster my interests in science. He encouraged me to go to university, saying it would be a waste of a good brain if I did not go." [South Africa]

"Both my parents supported my interest in science. My parents bought me a telescope, a chemistry set, geology kits, and electronic kits. My mother woke me up for every US space launch and watched the paper for special astronomical events." [USA]

"I owe a great deal to my father. Reading books and biographies of scientists, books like 'Fun with Science' motivated me for research." [India]

"My family's support, particularly my mother's [was important to my success]. She is an elementary school teacher and always encouraged me to study." [Mexico]

"My father was a physics teacher and taught me the beauty of physics. I received an education focused on sciences and never felt I was treated different for being a woman." [Switzerland]

"My family allowed me to study as much as I wanted." [South Korea]

"I think I did it all by myself, but I can't ignore my big brother's support during my education." [Turkey]

Encouragement From High School Teachers

High school teachers have a critical role on several levels. They have the responsibility of teaching students about both the subject matter and the excitement of a field. They also have the opportunity to affect students' confidence in their ability to succeed during the period when many students first make choices about eventual fields of study.

Almost one-third said they were influenced to choose physics by their teachers. However, about one-fourth rated the teaching of high school physics as worse than other subjects in their country.

"I was very fortunate to have an excellent science teacher in high school. We did experiments and I was utterly fascinated by the accuracy in some of the results. I think that having the opportunity to actually see first-hand the confirmation of what one learned in class made a deep impression on me and was very satisfying." [South Africa]

"I had talent in physics and mathematics, but the middle school teacher of mathematics (he was a male) didn't care for me. He was dismissive of girls' abilities and didn't like for girls to be the first in the class. While the teacher of physics (she was female) took care of me, she supported me and encouraged me to study physics, worked with me by giving me difficult exercises, laboratory work and different books in physics." [Albania]

"My secondary school teacher was a scholar and taught us so well that everyone in my class was interested in physics." [Nigeria]

Undergraduate Education

Undergraduate education is a unique stage in the educational system for several reasons. It is the first time that students publicly declare their intention to pursue a particular field of study. It is the first time that many students will meet practitioners in their intended field. It is also the first time that one field will make up a considerable portion of their studies.

Professors play an essential role during this stage of education. Imparting knowledge about the discipline is but one aspect of their responsibilities. No two students enter college with identical educational experiences and expertise. The best professors typically spend time with each of their students to identify the student's strengths and weaknesses. They then advise their students on ways to build on their strengths and address their educational shortcomings. Finally, professors represent the front line of their discipline. Thus, it falls to them to explain the excitement of their field and to encourage students to go as far in the educational system as their abilities will take them.

TABLE 4. Number of Undergraduate Physics Majors and Quality of Attention From Professors.

	Attention[a]	
	Positive	Neutral
Number of Majors	%	%
Fewer than 10	67	32
10–89	61	32
90 or more	45	45

[a] Rows do not sum to 100% because a few respondents chose "Negative" or "Other."

Almost all of our respondents were undergraduate physics majors, and almost all who were said they had received either the same amount of attention from their professors or more attention from their professors than the other students did. However, class size affects the quality of the attention that female physics students received (Table 4). Students who graduated from large departments reported less positive attention than students who graduated from smaller departments.

It should be noted that students who dropped out of physics were not included in this study. Thus, the fact that we received only a few negative comments about the attention professors gave to female students may not be representative.

"[When I was] an undergraduate, the majority of my professors and instructors were very good and very helpful. There was always a member of the department available to help with any questions or problems I had. The value of positive, enthusiastic teaching staff is enormous." [Canada]

"I got a lot of attention, all the help I needed—and sometimes more. I felt respected by the professors at the institute." [Denmark]

"I only decided to purse a career in physics during my undergraduate years, as a result of having some excellent and inspiring lecturers." [Ireland]

"My experience with university professors was patchy. Some were always ready to help, never too busy to answer a question and never made me feel small. Others were simply indifferent, while others took a special delight in taking students down a peg, reminding us that we were not as lofty as they and all but discouraging us from continuing with physics as a career. From these last groups I feel that I received little beyond the actual material presented to me by them." [South Africa]

Graduate Education

Graduate physics education provides students with knowledge of physics and an understanding of the basic principles that govern how the physical world works. However, a physics education does even more. It also provides students with the research and cognitive skills that are important for a good physicist. These include critical and analytical thinking, problem-solving skills, and learning how to define a problem and identify a set of possible solutions. In graduate school, students learn to look at the world in the unique way that physicists do.

"I believe that a...physics degree develops the ability to think laterally, to work through processes and consider all avenues before development." [Ireland]

In addition, physics students also acquire technical skills such as advanced mathematics, computer skills (both hardware and software), and the ability to work with lab equipment, including using, designing, building, and repairing sophisticated equipment. Finally, physics provides students with educational experiences that are intended to develop the traits that are important in good scientists, such as being hard working, meticulous, persistent, tenacious, and self-confident. In other words, in graduate school, students learn the culture of physics. They learn how to think like a physicist, communicate like a physicist, and work like a physicist.

Given the importance of graduate school, a good advisor can make all the difference in the professional success of a young physicist. The women who responded to our survey tended to have supportive graduate school advisors. Almost all of our respondents said that they had no difficulties finding an advisor, and almost all of the advisors were male. More than four out of five described their relationships with their advisors as either excellent or good, and most say that their advisor treated them better or the same as other graduate students.

> *"[I had a] female advisor/mentor in graduate school who made sure I was introduced into the scientific community, learned how to write proposals and papers, and otherwise did all the things advisors ought to do for their students but, in my opinion, rarely do." [USA]*

> *"I was always pushed forward by my Ph.D. chiefs—two women!!!" [France]*

However, graduate school was not a welcoming environment for all of our respondents.

> *"In graduate school, I was in an extremely hostile environment and miserable with no support from any of my research group. But, I was tough and fought to stay in grad school. It was an incredibly sexist place, but the fact that if I quit, that would cut the number of women in the physics class by 50%, kept me struggling to survive." [USA]*

Graduate education is the time when students learn to do research. In a positive educational atmosphere, students present their research at conferences and learn to write professional papers. During graduate school, almost three-fourths of our respondents were asked to present a poster or a talk at a conference, and two-thirds were asked to co-author a paper. However, only about half were asked to write a research paper on their own while they were in graduate school (Table 5).

TABLE 5. Percentage of Responding Women Physicists Who, in Graduate School, Were Asked to:

Present a poster/talk at a conference	72%
Co-author a research paper	66%
Write a research paper independently	47%

Exposure to International Research Opportunities

A physics Ph.D. is a research degree, and opportunities to do physics research are essential. A significant aspect of developing research expertise involves participation in international research projects. Many physicists make research visits to foreign countries or even move internationally to pursue careers. However, most of our respondents went to undergraduate school and graduate school in the same country in which they currently work. Three-fourths of these have made research visits to foreign countries at some point in their careers.

> *"A specific opportunity [that led to my success] was the fact that my university was closely related to the Joint Nuclear Research Institute (JINR). I visited JINR 11 or 12 times for short stays of about one month, but it was very important to meet people and to work in an international environment." [Bulgaria]*

> *"The support of my research advisor was integral to my success. Specifically, the opportunity to interact with international researchers and to attend and present my work at conferences was a major factor in attaining my current status." [Canada]*

"While at university, I had the good fortune of being able to spend several months before my senior undergraduate year as a summer research intern at a university in the USA and then the summer before my graduate studies at the CERN summer school. This gave me invaluable insights into modern physics research and gave me contacts and interests that helped form my career in a decisive way." [Germany]

"I worked in a group of young theoreticians with a successful leader who had international contacts." [Estonia]

Career

The importance of a Ph.D. for becoming a professional physicist varies by country. For example, Italy did not offer Ph.D.'s in physics until the 1980s. Most of our respondents, however, do have Ph.D.'s (Table 6).

TABLE 6. Highest Degree Obtained by Women Physicists Who Responded.

	Percent
Ph.D. or higher	65
Less than Ph.D.	20
Current student	14
Unknown	1

In addition to Italy, there are a few other countries where many of our respondents do not have Ph.D.'s (Table 7). It may be that physicists in these countries work without Ph.D.'s. On the other hand, a low percentage of respondents with Ph.D.'s may be an artifact of the sample. Respondents knew each other, and someone without a Ph.D. may have forwarded the questionnaire to her colleagues who also did not have Ph.D.'s. Women who work in developed countries are not more likely than women who work in developing countries to have Ph.D.'s.

In many countries, doing one or more postdocs after receiving a Ph.D. is also essential to a successful career. A little more than three out of five of our respondents who have Ph.D.'s worked as postdocs, although postdocs were more common in some countries than in others (Table 8). Of those who did work as postdocs, about half worked in academic settings for their postdocs. About three-fourths of those who worked as postdocs worked four or fewer years.

Among the women who responded to our survey, those from developed countries were much more likely than women from developing countries to have postdocs. Most respondents from developed countries had postdocs, while the majority of respondents from developing countries did not (Table 9).

Academia continues to be a primary employer for physicists. Two-thirds of our respondents are employed in academia. Of these, about two-thirds have tenure or a permanent position. Most respondents from academia say

TABLE 7. Countries Where 40% or More of the Women Physicists Who Responded Do Not Have Ph.D.'s.[a]

China-Beijing
Indonesia
Ireland
Italy
The Netherlands
Nigeria
South Africa
Turkey

[a] List compiled from 29 countries with 10 or more respondents who were not students.

TABLE 8. Countries Where 70% or More of Respondents With Ph.D.'s Had Postdocs.[a]

Belgium
Brazil
Canada
Denmark
Germany
United Kingdom
United States
Countries Where Less Than 45% of Respondents With Ph.D.'s Had Postdocs.[a]
Russia
Yugoslavia

[a] Lists compiled from 15 countries with 10 or more respondents to the second version of the questionnaire.

TABLE 9. Percentages of Responding Women Ph.D. Physicists Who Had Postdocs.

	Country	
Postdoc	**Developed**	**Developing**
Yes	73	46
No	27	54
	100%	100%

TABLE 10. How Quickly Have You Progressed in Your Career Compared with Colleagues Who Completed Degrees at the Same Time as You?

	Percent
More quickly	19
About the same	48
More slowly	33
	100%

that it took them the same or less time as their colleagues to get tenure. However, one-third of all respondents felt that they had progressed more slowly in their careers than their colleagues (Table 10). And about one-fifth said that they had less funding and equipment than their colleagues in similar positions or stages.

In addition to earning an advanced degree and possibly taking a postdoc, other steps can be taken in order to have a successful career. Physicists serve on committees, review others' work, and present their research at conferences. The majority of our respondents have given invited talks at conferences. Almost half have acted as referees for journals and have served on important committees at their institutes or companies. Almost two-fifths have served on steering committees for conferences. However, the majority say that they have not served on committees for grant agencies or as editors of journals (Table 11).

TABLE 11. Percentage of Responding Women Physicists Who Have Participated in the Following Activities:

Activity	**Percent**
Given an invited talk at a conference	52
Acted as referee for a journal	49
Served on important committees	46
Served on a conference steering committee	37
Served on committees for grant agencies	19
Served in an editorial position for a journal	12

Although half of the respondents say that they have served on important committees, it should be noted that women are often excluded from committees that have real power in their institutions and are relegated to less important committees. Regardless of the prestige and power of the committee, women are assigned too often to committees as tokens, and are effectively excluded from having any real input into the decision-making processes of the committee.

"I am convinced that the situation would improve if more women were on the committees dealing with careers, distributions of funding, choosing candidates for a position, etc." [France]

How do respondents think they compare to their colleagues at similar stages in their careers? Almost one-third say that they have served on steering committees for conferences less often than their colleagues have. About one-fourth say they have served as referees for journals and as editors less often than their colleagues. Almost one-third say they have given invited talks less often than their colleagues have.

Marriage

Women physicists who responded to the survey have mixed reactions about marriage. Some see it as a benefit, but many find it detrimental to their careers, especially because it can bring the problem of finding a job near one's spouse. More than one-fourth of the women who responded have never been married, and many chose this route in order to focus on their careers.

"If I would have gotten married, I could have no career." [Spain]

For the women in our study, marriage patterns are different in developed countries than they are in developing countries. Respondents in developing countries are more likely than respondents in developed countries to be married. In fact, one-third of respondents from developed countries are not married, and only one out of five

respondents from developing countries are not married. Respondents in developed countries are also more likely to wait until after receiving their final degrees to get married than respondents in developing countries are (Table 12).

Of those who did get married, more than one-third waited until after their final degree to get married, but about half got married during graduate school. About two out of five of those who got married said that marriage affected their work (Table 13). For many the effect was negative, and many of these mentioned the difficulty of finding jobs near their husband's place of employment.

TABLE 12. Timing of Marriage for Women Physicists Who Responded to the Study.

	Country	
	Developed %	**Developing** %
During school	36	59
After final degree	31	21
Never married	33	20
	100%	100%

TABLE 13. Countries Where More Than 50% of Women Physicists Who Responded Reported That Marriage Affected Their Work.[a]

Country	Percent
Egypt	73
United States	60
Russia	59
Germany	57
South Africa	55
Croatia	55
Japan	54
South Korea	53
Countries Where Less Than 30% of Women Physicists Who Responded Reported That Marriage Affected Their Work[a]	
Turkey	28
Argentina	26
Indonesia	25
France	24
Ireland	24
Latvia	20
China	19
United Kingdom	19

[a] Lists compiled from 26 countries with 10 or more respondents who have been married.

"I left my tenured position in one of the famous universities of India to join my husband in Brazil in 1975. I waited for two years to get a job in Brazil. The teaching job that I got was in a small university where there were only undergraduate studies." [India]

"I turned down faculty opportunities in Canada to be with my husband in USA. I took a technician job so we could live together. This has slowed down my career." [Canada]

"I delayed leaving the country for a postdoc position and instead started a postdoc in the same group where I did my Ph.D. But finally, since it was not possible to have appropriate positions in the same place in the long run, we got divorced. Only after that I considered to go abroad in order to start a career in science." [Germany]

"I had to leave the US and return to Israel as a postdoc because my husband wanted to come back to Israel. This was after he followed me to the US for my Ph.D. and first postdoc. I still managed to get a postdoc [in the US] in addition to my [other] postdoc position, and to divide my time between Israel and the US. However, I'm certain it would have been better for my career if I stayed continuously in the US." [Israel]

"My work became less important than that of [my] husband. I had to follow his moves, which meant starting again every 3 years." [Belgium]

Other women said that the effect of their marriage was positive because they had married another physicist, or because their spouse was particularly supportive, or because the routine chores of daily life were now shared by two people.

"[Marriage affected me] very positively, my husband has greatly sustained me during difficult periods of my career, both psychologically and by giving moral support, and practically, by taking over more household duties when I had a very heavy workload or pampering me when I had to recover from particularly stressful times. I would never have been able to work as hard and to produce as many papers had he not been constantly on my side." [Belgium]

"I have a lot of support from my husband—he is somebody who would spend an entire weekend in the lab with me if that is what is needed. Without his support, I would definitely not have completed a Ph.D. Of course, a relationship and home life takes time—but I would not change that for anything!"[Argentina]

"[Marriage gives one] something better to do than work through the night." [USA]

"I worked more because he was also in grad school, we encouraged each other." [Brazil]

"I discuss my work at home. My husband is also an astronomer, and a computer wizard, so he helps me by writing programs for me as well." [Netherlands]

"[Marriage] allowed me to devote myself to my studies in a more directed manner: I spent less time at work but improved my working efficiency. Meals and routine chores were shared and became less of a burden." [Canada]

The perception that marriage affected work varied greatly in different countries. In some countries, such as Egypt, the US, and Russia, a majority of married women said that marriage had affected their work. In other countries, such as China-Beijing and the UK, very few women said that marriage had affected their work (Table 13).

Children

In most societies, cultural expectations place most of the responsibility for child care on women. Therefore, most women physicists who have children are typically responsible for child care. They must find ways to balance the demands of their careers with the demands of their family responsibilities. There are cultural pressures to succeed as mothers and wives, and there are scientific pressures to succeed as physicists.

"The main reason, in my opinion, that women physicists rarely reach the highest levels of the professional career is that the society expects them to take (complete) care of the family and children. Our husbands do not like housework at all and they are not ready to share the responsibilities. Hence, spending a lot of time in the house and [on] the children, women physicists have less time to work at the lab. Soon, they become less competitive. Sometimes they have not enough time to follow the new achievements, and slowly they convert to teachers only. Their research suffers." [Bulgaria]

"The odds are stacked against women very subtly and mostly in the form of guilt about neglect of family and children, from family and loved ones at home. That's a combination that's hard to beat. So some kind of awareness among the general public about why it's important for women to hold their jobs and make a mark is also an essential ingredient in getting more women into research, and keeping them there." [India]

"I think many of the problems stem from societal reasons, and these will probably iron out to some extent with time. We have different traditional systems, and they mostly place the women in caring roles (often confined to the home). These coexist with 'modern' roles, and the so-called 'career women' of today spend a good fraction of their energies trying to bridge the divide between what is expected of them at work and at home. Some of the compromises we must make don't earn us much credit in either sphere of action, and can be quite demoralizing!" [India]

"Awareness should be aroused in the society regarding sharing of family responsibilities, so that it becomes easier for women scientists to balance family and career." [Pakistan]

"Since all the burden of raising children falls on the shoulders of the women, there are small chances for them to progress at the same rate as men in the same position." [Israel]

"I think that the situation for all women should be improved as the women are left almost all by themselves to raise the children, work, and take care of the house." [Brazil]

"I believe it is a social problem, not directly related to physics. As long as the housework and children care will not be equally shared by men and women, it will be considerably more difficult for women to be successful in a career, whatever this career is." [France]

Unfortunately, the culture of physics includes the requirement that physicists work long hours. With this comes the related belief that anyone who has to limit her work time is less productive. Women are keenly aware of these beliefs. Some react by concluding that work and family are incompatible and choose to leave physics (unfortunately these women could not be included in this study). Some chose career over family and made the choice not to have children. More than two out of five of our respondents have not had children. Of those older than 45, more than one-fifth have not had children.

Other women have families, but keep putting in the long hours, often returning to the lab after the children are in bed. Still others say that they simply became more productive during the hours they are at work.

"People in science should agree that science is an important part of the life of a scientist—but it's not all of his/her life!!! Everybody in science has the right to have time for family, friends, hobbies. The quality of scientific work of a person does not depend on whether or not this person has also further interests. And scientists should not become slaves of their work because they need or want a new contract or a permanent job at one point. Leaders of research groups, institutes or facilities should not make them slaves. In this sense the culture of work in science has to change a lot." [Italy]

"My husband couldn't understand why I was tired all the time, why I worked so many nights and why I spent most weekends marking tutorial problem sheets." [Australia]

"Having a daughter [while I was] in graduate school gave balance to my life. I spent less time in lab than some of my male colleagues but used my time more efficiently. It definitely changed my work patterns but did not make me less productive." [USA]

"I believe [having a family] taught me to work more effectively, to use my precious time." [Poland]

Among all respondents who had children, the majority waited until after their final degrees to have them. This places most of them into their 30s at the birth of their first child and interrupts research demands just when they are trying to start their careers. The pressure is particularly strong on those who are trying to obtain tenure in academic jobs.

"[Allow] greater flexibility in postdoc to tenure-track, which would allow childbearing without committing career suicide." [USA]

"It would be desirable to have some kind of "sabbatical year" in order to alleviate the pressure for publication and other production for those who have babies." [Argentina]

"I think it would be an advantage if a rule existed that when you apply for a research job, the time you have been on maternity leave doesn't count when they evaluate your list of publications." [Denmark]

Another strain comes from the expectation that physicists make international research visits a priority, as many of our respondents did. Travel is particularly difficult for women with very young children. One respondent reported that a woman she knew had left physics altogether because she was *"asked to go abroad for one year, just after she had a baby." [Italy]*

The cultural expectations to have children are often very different for women in developing countries than they are in developed countries. Respondents from developed countries are much more likely not to have children than those from developing countries.

- More than half of all respondents from developed countries do not have children, but less than one-third of respondents from developing countries do not have children (Table 14).
- Among respondents over age 45, about one-third from developed countries do not have children, but only one in ten from developing countries do not have children.
- Among respondents with children, those from developing countries are much more likely to have them during school than respondents from developed countries are. Respondents from developed countries generally waited until after their final degree to have children (Table 14).

The majority of women with children said that having children affected their work. For example, women with children were more likely to say their career had progressed more slowly compared to their colleagues than women who do not have children (Table 15).

TABLE 14. Timing of First Child for Women Physicists Who Responded to the Study.

	Country	
	Developed (%)	**Developing (%)**
During school	13	40
After final degree	33	30
No children	54	30
	100%	100%

TABLE 15. Effect of Children on How Quickly Responding Women Physicists Say They Progressed in Their Careers Compared With Their Colleagues.

	Children	
	Yes (%)	**No (%)**
More quickly	15	23
About the same	45	52
More slowly	40	25
	100%	100%

"Prejudices still exist in the scientific community that a woman who has children usually is not as engaged any more in research like her male colleagues (usually they are fathers and nobody has ever questioned their engagement)...[And there is] the prejudice that the quality of scientific work depends on the time one spends in the lab or office, and the wish of the chiefs to keep their people under control, which means that they do not like (or even believe) that parents work at home sometimes. Many women scientists do not want to live without family/children. Several give up science when they get children as they know, from female friends or colleagues, how hard life is for a mother in physics. Many of those who try to have both, work and family, are soon de-motivated by reality." [Italy]

Evaluation of the Situation of Women in Physics

Although more than three out of four said they would choose physics again, three out of four also said the situation for women in physics in their country needs to be improved. When asked to describe how the situation could be improved, the most frequently mentioned factor had to do with reducing the burden child care places on women. Women mentioned making day care more available or convenient, taking steps to make travel easier during the years when children are young, and having husbands who do their share of child rearing.

The second most frequently mentioned way to improve the situation of women in physics had to do with ending discrimination either across society, or more locally at their individual jobs or schools. These situations are, of course, not unique to physics.

"In the countries I know (Spain and Switzerland), I believe it is not difficult for a woman to become a physicist, if she really wants to. However, it is not true that equality among men and women has been achieved in these countries. I see, for instance, that my daughter (4 years) still receives a considerable pressure at school and from the society to accept the old feminine roles." [Switzerland]

"In my country, as in many others, there is a strong 'machismo.' Men feel diminished if a woman competes with them. Many times they don't mean it, it is just 'the culture.' Some other times, harassment is made on purpose. It is 'always understood' that women are 'frauds,' even compared to the worst male coworker." [Mexico]

"Overall, the difficulty is that women are not seen by men, or in fact by the society as a whole, as likely scientists. This impression influences the attitudes at school and the self-image of young girls and continues to the highest levels when salary is affected for female academics." [Netherlands]

"There are still incidences of sexual harassment, usually in the form of sexual advances that do not stop after verbal requests for them to stop, or illegal questioning about childbearing plans." [USA]

"[The situation for women in physics will improve] if they start treating women as human beings..." [Japan]

"Of course it is also important to make sure that structures are in place to address the problem of discrimination against women. However, from [my] own experience I know that most of the times discrimination takes on a very subtle form. The only way to address it, is to educate women to challenge the culprits. People tend to laugh off laws and official enquiries, however they start to think if they are challenged time and time again by a person." [South Africa]

"In industry, some years ago, I have been subjected to unwanted sexist remarks—(i)size of my [breasts] discussed in front of whole team, (ii) criticized for not wearing make-up as a technical specialist on a trade show booth." [UK]

"I also believe that most of the leading names, certainly in my area of interest, are male and make male decisions. This has enormous consequences for any female young scientist." [Ireland]

"And the attitude that physics is for men must be brushed out!" [Tanzania]

More than two-thirds said that they knew a woman who had left or given up physics. The most frequently mentioned reason for women giving up physics was that they left for family reasons (marriage and/or children). The second most frequently mentioned reason was that they left for a different job, field, or career. Also frequently mentioned was the difficulty of finding a permanent job in physics, which is likely worse for married women.

"[I know women who left physics] simply because they could never get proper positions as physicists, though most of them had the same kind of abilities as their male colleagues." [Japan]

Success in Physics

We asked what factors women thought had contributed to their success in physics. The most frequently mentioned factor was the support of their families, including their parents and husbands. Many also mentioned the support of advisors, professors, and teachers, and some cited the support of colleagues.

"[My success is due to] the support of my husband, who is also a physicist, and who was with [our] kids during my long-lasting experiments or some conferences." [Croatia]

"My family too went all out to support me—my mother with child care and many other things, my husband does at least half the housework and often gives up opportunities if they are inconvenient to my schedule." [India]

"I had the opportunity to work with a very well known professor for a short time. He supported me and encouraged me a lot. It was also psychologically very important for me to see that I could collaborate with one of the best physicists at the time." [Switzerland]

Also frequently mentioned were the women's own determination, will power, and hard work.

"I am very stubborn and when I was told that I could not become an astrophysicist because 'I was not bright enough' or because 'women are not cut out for that' or because 'you cannot have a research career when you have children,' I want to prove them wrong." [Denmark]

"Only my own skills and abilities [contributed to my success]. There was no specific support for women at that time. I think what helped most was my own stubbornness to try things which no one expected me to manage, and see the success after each exam." [Germany]

"I was motivated to work hard because people said the blonde little girl couldn't do physics. I enjoyed the subject and didn't mind working hard at it. I got a lot of satisfaction from working hard and achieving." [USA]

"[There were] stupid (male) lecturers in university who advised me not to work abroad or step over my limits. Therefore, I put even more effort into it, and fortunately I got a lot of support from acquaintances who were convinced of my skills." [Ireland]

CONCLUDING REMARKS

Women pursue careers in physics because they have a passion for the field. They succeed because they are smart, they are determined, and they work hard. In short, they are a remarkably valuable resource for the educational systems and the economies of their countries.

We asked women physicists if they would choose physics again. Three out of four replied that they would. One of the goals of the conference was to identify ways to get this number closer to 100%. Another goal was to identify the changes that will make it possible for the next generation of women physicists to succeed in school and to have the opportunity to successfully pursue careers in physics.

Many women succeed in physics despite tremendous obstacles. All over the world, women physicists report similar barriers to their success. The cultural pressure to be caretakers of children conflicts with the scientific pressures of physics. Women also face barriers in the form of strongly held beliefs that women are incapable of doing good science.

However, women also report similar keys to success regardless of their country. Over and over again, women mentioned the support of others—families, husbands, teachers, advisors, and colleagues—as integral to their success. There is also the continual reference to women's own strength and determination in the face of barriers. These women relied on themselves and on others, and became successful physicists.

"Physics is a subject I love very much and I don't think I can stop learning new things about physics." [Nigeria]

"I think physics is a fantastic thing to do." [Sweden]

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SOURCES FOR COUNTRY-LEVEL DATA AND ANECDOTAL INFORMATION

Albania: Prof. Antoneta Deda.

Armenia: Collected through personal correspondence. Supplied by Dr. Inna G. Aznauryan.

Australia: Compiled from datasets available from the Australian Commonwealth Department of Education, Training and Youth Affairs (Higher Education Division).

Cameroon: Dr. Ndukong Tata Gerard and Dr. Samba Odette Ngano.

Canada: Association of Universities and Colleges of Canada.

Chile: Collected from individual physics departments. Supplied by Dr. Dora Altbir and Dr. M.C. Depassier.

China-Beijing: Dr. Ling-An Wu.

China-Taipei: The Taipei Economic and Cultural Representative Office in Washington, D.C.

Columbia: Instituto Colombiano para el Fomento de la Educacion Superior, and personal correspondence. Supplied by Angela Camacho Beltran.

Croatia: Personal correspondence with physicists at institutions. Supplied by Vjera Lopac.

Czech Republic: Josef Humlicek.

Denmark: *Kandidater i Matematik-, Fysik-og Kemifagene: HVOR GIK DE HEN?* www.uvm.dk/nyt/pm/gik1.pdf.

Estonia: Personal correspondence with physicists at institutions, and homepages of institutions. Supplied by Helle Kaasik.

France: National Ministry of Education.

Germany: Federal Statistical Office Germany.

India: Registrar General of India, Ministry of Human Development.

Iran: Collected from the government and personal correspondence. Supplied by Dr. Azam Iraj-zad.

Israel: Prof. Halina Abramowicz.

Japan: Collected from the Ministry of Education and personal correspondence with another government office. Supplied by Dr. Hidetoshi Fukuyama.

Lithuania: First-level degree information from personal correspondence with universities. Ph.D. information from *Collection of Lithuanian Physicists and Astronomers,* 2nd edition (Lithuanian Physical Society and State Institute of Physics, 2001). Supplied by Alicija Kupliauskiene.

Mexico: First-level data are from direct correspondence with the Asociacion Nacional de Universidades e Instituciones de Educacion Superior (ANUIES). Ph.D. data are from *Anuario Estadistico 1999: Poblacion Escolar de Posgrado*, published by ANUIES.

Norway: Personal correspondence with institutions. Data supplied by Ashild Fredriksen.

The Netherlands: The Dutch Physical Society.

Poland: Central Statistics Office of Poland.

South Africa: Collected through personal correspondence. Supplied by Jaynie Padayache.

South Korea: Embassy of South Korea in Washington, D.C. Supplied by Gayle Juenemann.

Sudan: Collected through personal correspondence. Supplied by Prof. Osman Mai Eltag Mohamed.

Sweden: National Agency for Higher Education.

Switzerland: Swiss Federal Statistical Office.

Turkey: Center for Student Selection and Placement.

Ukraine: *Scientific World.* Supplied by Dr. Oksana Patsahan.

United Kingdom: Higher Education Statistical Agency.

United States: The American Institute of Physics.

Federal Republic of Yugoslavia: Collected by several members of the Yugoslavia working group for physics. Supplied by Dr. Mirjana Popovic-Bozic.