

CHAPTER 1

Science Anxiety: Research and Action

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Science anxiety has been shown to seriously impede student learning. This chapter will describe research done on science anxiety and will explain specific actions that college science teachers can take to build the confidence of their students.

In 1977, I identified the phenomenon for which I coined the term *science anxiety*. It usually manifests itself as a crippling panic on exams in science classes, but it is distinct from general test or performance anxiety. Students suffering from science anxiety are often calm and productive in their nonscience courses, including their mathematics courses.

The first Science Anxiety Clinic was founded at Loyola University Chicago (Mallow 1978). Techniques that we developed in the clinic reduce science anxiety by blending three separate approaches: (1) science skills learning, (2) changing of students' negative self-thoughts, and (3) desensitization, through muscle relaxation, to science anxiety-producing scenarios (Mallow 1986). Several studies were carried out with students at the Loyola University Science Anxiety Clinic (Alvaro 1978; Hermes 1985) to assess its effectiveness. A variety of instruments were used, including three questionnaires: the Mathematics Anxiety Rating Scale (Richardson and Suinn 1972), a general anxiety measure (Spielberger, Gorsuch, and Lushene 1970), and a general academic test anxiety measure (Alpert and Haber 1960). In addition, the students' muscle tension was measured by electromyography while they imagined science anxiety scenarios, such as taking a physics test. Alvaro (1978) developed a Science Anxiety Questionnaire. She, and subsequently Hermes (1985), demonstrated that significant decreases in anxiety, measured by this instrument, by electromyography, and by the questionnaires described above, occurred for students in clinic groups over those in control groups.

Causes of Science Anxiety

The causes of science anxiety are varied. Numerous anecdotal reports suggest that students

receive negative messages about science throughout their school careers. Many, if not most, of the science teachers in the lower grades believe the same myth as much of the rest of society: that the talent necessary for doing science is given only to a select few. High school counselors often advise students to avoid more than the minimum science, especially physics, to keep their grade average high and thus improve their chances of getting into college.

Students frequently receive little or no training in analytical thinking in the early school years, and even through high school. Memorization is stressed to the detriment of other skills. Science courses in the lower grades are generally descriptive. Emphasis is often on the “gee-whiz” kinds of demonstrations that keep students interested without teaching them very much. The true nature of science as a puzzle to be solved is not made clear. Confronted with the reality of science, many students become anxious.

Teachers may also provoke anxiety. Who, for example, is teaching physics, the least populated of high school science courses? An American Institute of Physics (AIP) study at the beginning of this millennium (AIP 2001) yielded the startling statistic that only 47% of the people teaching physics in high school had either a minor or more in physics or physics education; only 33% had a bachelor's degree with a physics or physics education major. Who are the others, what are they teaching, and what view of science do they communicate? Are they themselves anxious?

Science anxiety is affected by role models, or the lack thereof. Despite marked decreases in some gender disparities in science study, males and females still follow traditional patterns (Mallow 1994, 1998), with physics the field with the fewest female students (Tobias, Urry, and Venkatesan 2002). The low numbers of female (and minority) physics teachers depresses the number of students who might see themselves as future physicists. For the 2000–2001 academic year, only 29% of high school physics teachers were women (AIP 2001); the percentage of female faculty in all university physics departments was 10% in 2002, up from 6% in 1994. Although these numbers have improved over the last few years, there is still sufficient disparity to discourage young women from considering physics as a career. In addition, high school counselors still selectively steer females away from math and science. This appears to be true for female as well as male counselors, and it is not restricted to the United States.

Last but not least in the science anxiety pantheon are the still-prevalent stereotypes of the scientist: male, geeky, intelligent but boring, hardly a role model (Rahm and Charbonneau 1997). Vedelsby (1991) documented these stereotypes in Denmark, even among science students. “They are little boys with round glasses, and they always look boring. We call them owls.” was the comment of a female medical student about physics students. Universities are still divided into humanities and sciences—in different buildings and rarely interacting with each other. More than a few humanities professors still promulgate the stereotype of the warm artistic soul versus the cold scientific brain. (The Austrian modernist writer Robert Musil satirized this attitude in his novel *The Man Without Qualities*, in which he says, “What is a soul? It is easy to define negatively: it is simply that which sneaks off at the mention of algebraic series.”)

Science Anxiety Research

Instrument and Analysis

The Science Anxiety Questionnaire (Alvaro 1978; Mallow 1986, 1994; Udo et al. 2001), used in all of our research studies, is a 44-item questionnaire that asks students to imagine themselves in certain situations and to rate their level of anxiety on a 5-degree scale: “not at all,”

“a little,” “a fair amount,” “much,” or “very much.” Items are evenly divided between science and nonscience content, with emphasis on analogous situations, such as studying for a science exam versus studying for a humanities exam. The questionnaire is provided at the end of this chapter as an appendix.

We analyzed the questionnaires in two ways: (1) by multiple regression analysis on all responses and (2) by chi-square analysis on “acute anxiety”: the number of students who gave “much” or “very much” responses to one or more of the 44 items. This acute anxiety was characterized as “general anxiety” if there were “much” or “very much” responses to any item. Acute general anxiety was then subdivided into acute science anxiety: “much” or “very much” responses to any of the 22 science items, and acute nonscience anxiety: “much” or “very much” responses to any of the 22 nonscience items. Figure 1.1 summarizes the terminology of science anxiety.

The Role of Gender and Nationality

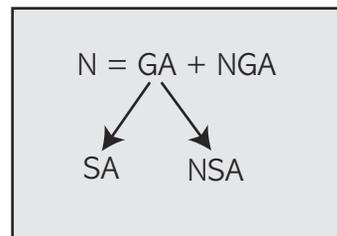
In U.S. science anxiety clinics, the majority of the clientele has been female. Chiarelott and Czerniak (1985, 1987) discovered that science anxiety starts as soon as children begin to learn science: age 8 or younger in the United States. Greater science anxiety among girls begins at the same time.

Contemporaneous with our activities, a group of female physics teachers was doing similar work in Denmark (Beyer et al. 1988). I undertook a study to investigate whether science anxiety was related to gender, and whether it varied across national lines, between American and Danish students (Mallow 1994). I found that in both groups, females scored higher on science anxiety than did males. Science anxiety proved also to be related to general anxiety and to field of study, with nonscience students (not surprisingly) having more anxiety. For those students who expressed acute science anxiety (giving “much” or “very much” responses to one or more of the science items), Danish females and males registered lower anxiety than their American counterparts of the same gender. Furthermore, Danish females registered slightly lower than American males (see Figure 1.2). These results suggest several conclusions. First, there is little likelihood of a “natural” female tendency toward science anxiety. Second, remediation attempts, both pedagogical and psychological, that are effective for one gender should be effective for both; the same is true for different nationalities. This has been shown to be the case in the American science anxiety clinic (Alvaro 1978; Hermes 1985) and in the Danish classroom (Beyer et al. 1988).

In a subsequent study (Mallow 1995), I considered the national differences in anxiety discussed above and examined whether the nature of science teaching plays a role. Do the Danish teachers make different choices in the classroom than their American counterparts? The American Association of Physics Teachers (AAPT) created a workshop, *Developing Student Confidence in Physics* (Fuller et al. 1985), to assess and modify teachers’ styles. One of its features is a Personal Self-

Figure 1.1

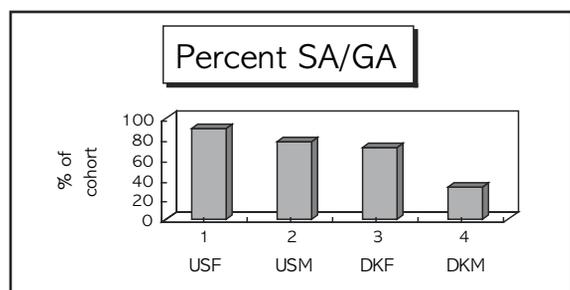
Terminology of Science Anxiety



N = total sample; GA = generally anxious (number of students who gave at least one “much” or “very much” response to any science or nonscience question); NGA = not generally anxious (number of students who did not give any “much” or “very much” responses); SA = science anxious (number of students who gave at least one “much” or “very much” response to any science question); NSA = nonscience anxious (number of students who gave at least one “much” or “very much” response to any nonscience question, but not to any science question).

Figure 1.2

Percentage of Science-Anxious (SA) Students Among Generally Anxious (GA) Samples, From Science Anxiety Questionnaire



Ranking from most to least anxious: U.S. females (USF), U.S. males (USM), Danish females (DKF), Danish males (DKM). SA students answered "much" or "very much" to any of the 22 science questions. GA students answered "much" or "very much" to any of the 44 questions.

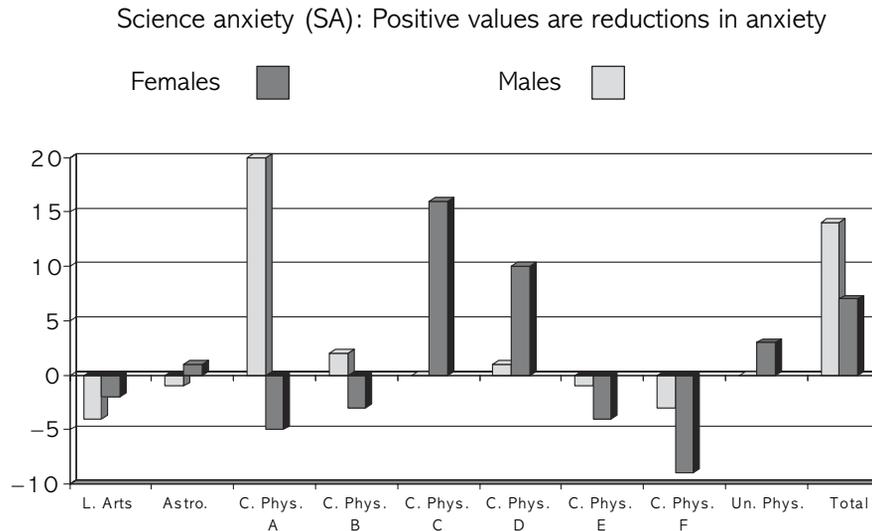
Inventory—a questionnaire describing various classroom scenarios and asking teachers to select their most likely responses. The inventory has been administered at national meetings of both the Danish Association of Physics Teachers (Fysiklærerforeningen) and the AAPT. Danish and American teaching practices sampled by the questionnaire do not seem to differ significantly and cannot therefore account for the lower Danish science anxiety. One possible explanation may simply be that constant exposure to science, from the early school years, makes Danish students more confident than American students. Another possibility is that Danish students keep the same teachers throughout primary school; this relationship itself might build confidence. Some U.S. elementary schools have begun experimenting with this method. Note, however, that neither greater exposure nor closer relationship to the teacher reduces the gender differences in science confidence. There is considerable evidence that even sensitive teachers

exhibit different behaviors to male and female students in both Denmark and the United States (and probably many other countries).

Using our Science Anxiety Questionnaire, Brownlow and her co-workers studied science anxiety in a group of American university students (Brownlow, Jacobi, and Rogers 2000). For their cohort, gender turned out not to be a significant predictor of science anxiety. However, females who were science anxious assessed their ability to do science less positively than males and took fewer science courses. Beyer and colleagues (1988) observed similar gender differences in Danish students.

The Role of Science Courses

We have examined the effect of an introductory physics course on science anxiety. Our cohort consisted of Loyola University students enrolled in introductory physics courses for non-science students, for pre-health and biology students, for chemistry students, and for physics and pre-engineering students. The Science Anxiety Questionnaire was administered unannounced on both the first day (pretest) and last day (posttest) of each class. This study (Udo et al. 2001) confirmed the results of the earlier study (Mallow 1994): The best predictor of science anxiety is nonscience anxiety; the next best is gender. Our pre- and posttest results showed that an introductory physics course tended to somewhat reduce acute science anxiety (see Figure 1.3). (We also found that nonscience anxiety decreased.) We found that different pedagogies, as well as gender role models, may correlate with anxiety reduction. Males taught by a man in an interactive physics course (lecture and demonstration plus group work) reaped some additional benefit, as did females in an interactive course taught by a woman. Finally, we discovered that anxious females tended to stay in their physics courses, whereas anxious males tended to drop out. This corroborates the findings of Seymour and Hewitt (2000) as to why students, male and female, choose to stay in or to leave science.

Figure 1.3**Changes in Acute Science Anxiety in a Semester of Physics**

L. Arts = Liberal Arts Physics, algebra-geometry based, for nonscience majors; Astro = Astronomy, algebra-geometry based, for nonscience majors; C. Phys = College Physics, algebra-trigonometry based, for biology and pre-health students (there are six sections, labeled A–F); Un. Phys = University Physics, calculus based, primarily for chemistry majors.

We have also measured science anxiety among university students taking required science courses for nonscience majors (Udo et al. 2004). We administered the Science Anxiety Questionnaire to several hundred humanities, social science, mathematics, business, education, and nursing students who were taking courses in biology, chemistry, and physics. (A few science majors also turned up in these courses. We include them for completeness in our results [Figure 1.4], but their absolute numbers were not significant.)

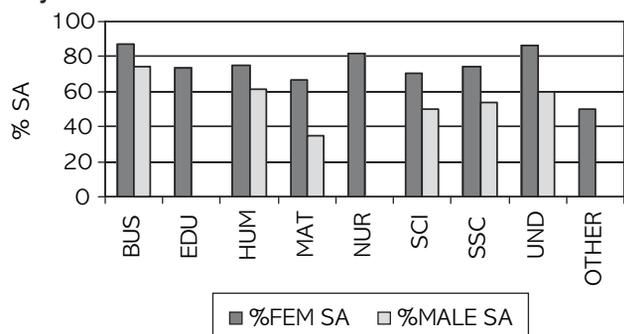
Comparing the results shown in Figure 1.4 with our earlier studies of science students (Udo et al. 2001), we conclude that

- Nonscience students, both female and male, are very science anxious, with acute anxiety percentages ranging as high as 88% of a group. Among the most science anxious students are our education majors, still almost all female, the teachers of the next generation. We also found that nonscience students are not only more science anxious but also more generally anxious than science students.
- Gender differences in acute science anxiety are especially significant among nonscience students.

A summary of the work in gender and science anxiety, as well as discussion of related issues, can be found in *Gender Issues in Physics/Science Education (GIPSE)* (Mallow and Hake 2002), a continually updated online list of references dealing with gender and science.

Figure 1.4

Acute Science Anxiety (SA) in Students in Various Majors



The percentage of students reporting acute science anxiety, in each course of study: BUS = business; EDU = education; HUM = humanities; MAT = mathematics; NUR = nursing; SCI = science; SSC = social science; UND = undeclared major.

But What Do We Do Monday Morning?

A variety of practices can help alleviate science anxiety. Nine recommended practices are discussed in this section.

1. *Explicit science skills teaching.* Frequently, students have been taught only the skill of memorization, which is not effective in understanding science. They must therefore be taught, for example, that one needs to read science differently from history or literature (Mallow 1991); that there are particular techniques for organizing and solving word problems; and that there are special ways to take notes in science classes, to perform effectively in science laboratories, and to take quizzes and examinations (Mallow 1986). Females in particular need to recognize that their learning depends on asking questions in and out of class and that they must have hands-on laboratory experiences.

2. *Group work.* This has been shown to enhance student performance and to improve retention in the major and at the university (Gautreau and Novemsky 1997; Hake 1998; Heller, Keith, and Anderson 1992; Mazur 1997; Meltzer and Manivannan 1996; Michaelsen et al. 1982; Treisman 1992). There is also an important gender component in group work. Females report that they prefer group projects to traditional lectures, because of the interactive, cooperative components and the control of individual competition (Beyer 1992; Legge 1997; Mallow 1993).
3. *Theme-based curricula.* Drawing students into science through themes is an effective way of providing them with a comfortable classroom environment. To do this in a whole course may be a fairly radical departure from the norm. It has, however, been successfully applied elsewhere (Beyer 1992). It can in any case be introduced as one element of a course (Mallow, Forthcoming).
4. *Attention to wait time and gender equity in calling on students.* When faculty pause frequently during lectures, students absorb significantly more information (Ruhl, Hughes, and Schloss 1987). Pauses for questions and discussion must be longer to invoke female responses (Didion 1997). In particular, when a teacher asks a question, he or she must wait at least 10 seconds for a reply (Fuller et al. 1985). The teacher must be especially vigilant about distributing the questions equally to both genders. Keeping a written record of which students have been called on is very helpful.

5. “*Catch students doing something right!*” (Fuller et al. 1985). The version of this approach that I have found effective is to stay with the student who has been questioned, work backward through Socratic dialogue until the student reaches the last concept that he or she understood, and then move forward to eliciting the right answer.
6. *Gender-equitable laboratory practice*. Most science teachers have observed male students’ eagerness to play with (and break) equipment, contrasted with females’ anxiety about doing the same. The remedy is careful monitoring of laboratory group practice, to make sure that groups are not divided into scientists and secretaries.
7. *Balancing content and relationship in teacher-student interactions*. The AAPT workshop (Fuller et al. 1985) focuses on four aspects of teaching:
 1. the classroom learning environment,
 2. information transfer between teacher and student,
 3. teacher-student interaction, and
 4. teachers’ evaluations of student performance.

The learning environment includes body language, tone of voice, word selection, and classroom organization by the teacher. Information transfer deals with all aspects of content, from course ground rules to teaching techniques, and how these can affect student confidence. Teacher-student interaction focuses primarily on the technique known as active listening, helping teachers modify their listening styles so that they hear the student’s whole agenda, not simply the one he or she presents. Even such subtle but critical items as placement of chairs in the teacher’s office are important. Finally, evaluation of student performance deals not only with fair and effective grading but also with the nature of comments on papers and tests and how these comments can diminish or enhance student confidence.

The workshop also deals specifically with issues of females and underrepresented minorities in the science classroom. Workshop “graduates” are then expected to bring these techniques not only to their own classrooms but to their colleagues as well. As noted earlier, I have used the workshop materials for binational comparison studies of teachers’ styles in the United States and Denmark (Mallow 1995). Several hundred teachers in at least two countries have benefited from training in science anxiety reduction. The workshop manual is available from AAPT.

8. *Explicit focus on metacognition*. Effective learning has been shown to be highly correlated with the use of metacognitive or self-regulatory skills (Beyer 1992). Monitoring “how we learn what we learn” can lower students’ anxieties in the classroom, while providing a unique way for students to process the material they are learning. This “stepping back” helps demystify the learning of science and undercuts the myth that there is a special, rare, and unteachable talent needed for doing so.
9. *Response to the wide variety of student learning styles*. This practice encompasses many of the other recommendations. The more multimodal the classroom—lecture, demonstra-

tions, group work, brief writing exercises, Socratic dialogue—the more students will be engaged and the less estranged and fearful they will be.

Conclusion

It is clear that college science teachers have a daunting challenge. Despite the numerous exceptions, many of our students come to us with the baggage of poorly taught pre-college science, lack of appropriate role models, and societal prejudices. This baggage is both cognitive and emotional. Thus, our task is not only to teach, but to teach in a way that will overcome students' anxieties. In addition to including confidence building in our own pedagogy, we need to increase collaborations such as university-sponsored inservice training courses for K–12 science teachers. Science anxiety reduction should become an integral part of such programs. We must be especially aware of the high level of anxiety among education majors, our future teachers. If we can succeed with them, then we will have taken an important step toward improvement of science education for the coming generations.

Appendix

Science Anxiety Questionnaire

Date: _____ Name: _____

The items in the questionnaire refer to things and experiences that may cause fear or apprehension. For each item, place a check mark on the line under the column that describes how much YOU ARE FRIGHTENED BY IT NOWADAYS.

	Not at all	A little	A fair amount	Much	Very much
1. Learning how to convert Celsius to Fahrenheit degrees as you travel in Canada.					
2. In a Philosophy discussion group, reading a chapter on the Categorical Imperative and being asked to answer questions.					
3. Asking a question in a science class.					
4. Converting kilometers to miles.					
5. Studying for a midterm exam in Chemistry, Physics, or Biology.					
6. Planning a well balanced diet.					
7. Converting American dollars to English pounds as you travel in the British Isles.					
8. Cooling down a hot tub of water to an appropriate temperature for a bath.					
9. Planning the electrical circuit or pathway for a simple "light bulb" experiment.					
10. Replacing a bulb on a movie projector.					

- | | Not at all | A little | A fair amount | Much | Very much |
|----------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------|---------------|------|-----------|
| 11. Focusing the lens on your camera. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 12. Changing the eyepiece on a microscope. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 13. Using a thermometer in order to record the boiling point of a heating solution. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 14. You want to vote on an upcoming referendum on student activities fees, and you are reading about it so that you might make an informed choice. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 15. Having a fellow student watch you perform an experiment in the lab. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 16. Visiting the Museum of Science and Industry and being asked to explain atomic energy to a 12-year-old. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 17. Studying for a final exam in English, History, or Philosophy. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 18. Mixing the proper amount of baking soda and water to put on a bee sting. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 19. Igniting a Coleman stove in preparation for cooking outdoors. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 20. Tuning your guitar to a piano or some other musical instrument. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 21. Filling your bicycle tires with the right amount of air. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 22. Memorizing a chart of historical dates. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 23. In a Physics discussion group, reading a chapter on Quantum Systems and being asked to answer some questions. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 24. Having a fellow student listen to you read in a foreign language. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 25. Reading signs on buildings in a foreign country. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 26. Memorizing the names of elements in the periodic table. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 27. Having your music teacher listen to you as you play an instrument. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 28. Reading the Theater page of <i>Time</i> magazine and having one of your friends ask your opinion on what you have read. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 29. Adding minute quantities of acid to a base solution in order to neutralize it. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 30. Precisely inflating a balloon to be used as apparatus in a Physics experiment. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |
| 31. Lighting a Bunsen burner in the preparation of an experiment. | | | | | |
| | Not at all | A little | A fair amount | Much | Very much |

32. A vote is coming up on the issue of nuclear power plants, and you are reading background material in order to decide how to vote.
Not at all A little A fair amount Much Very much
33. Using a tuning fork in an acoustical experiment.
Not at all A little A fair amount Much Very much
34. Mixing boiling water and ice to get water at 70 degrees Fahrenheit.
Not at all A little A fair amount Much Very much
35. Studying for a midterm in a History course.
Not at all A little A fair amount Much Very much
36. Having your professor watch you perform an experiment in the lab.
Not at all A little A fair amount Much Very much
37. Having a teaching assistant watch you perform an experiment in the lab.
Not at all A little A fair amount Much Very much
38. Focusing a microscope.
Not at all A little A fair amount Much Very much
39. Using a meat thermometer for the first time, and checking the temperature periodically till the meat reaches the desired “doneness.”
Not at all A little A fair amount Much Very much
40. Having a teaching assistant watch you draw in Art class.
Not at all A little A fair amount Much Very much
41. Reading the Science page of *Time* magazine and having one of your friends ask your opinion on what you have read.
Not at all A little A fair amount Much Very much
42. Studying for a final exam in Chemistry, Physics, or Biology.
Not at all A little A fair amount Much Very much
43. Being asked to explain the artistic quality of pop art to a 7th grader on a visit to the Art Museum.
Not at all A little A fair amount Much Very much
44. Asking a question in an English Literature class.
Not at all A little A fair amount Much Very much

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