

Ethics and Nanotechnology:

Mapping the Views of the NNIN Community

by

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NNIN Annual Meeting
Ann Arbor, Michigan
May 10, 2007

Preliminaries:

- Feb. 2003: NSF's NNIN RFP
- Each proposal had to indicate how **“social and ethical implications of nanotechnology”** would be addressed by the group submitting it.
- Mar. 2003: Stanford Nanofabrication Facility managers invited me to get involved with the group.
- To balance speculation about ethics and NT, I proposed to do a primarily empirical study of this topic that, if successful, would generate some hopefully useful, grounded knowledge.
- Focus of my study: **NT researchers' views about ethical issues related to their work.**
- Methodology: Web-based questionnaire.
- Questionnaire design: June 2004-Aug. 2005.
- Approval process for IRB/HSR committees: Feb. 2005-Mar. 2006.
- Survey period: **Sept. 2005- July 2006.**
- Hopes: survey findings provide useful inputs to (a) discussions of (a) NT lab safety, (b) other ethical issues, and (c) better non-technical education for future NT practitioners.

Slide 2

REM1

In 2003, I got involved with researchers at the Stanford Nanofabrication Facility, 1 of 13 U.S. university-based research organizations planning to submit a joint proposal to NSF to establish a national network of NT research centers.

NSF required that all proposals to do so have a component devoted to indicating how social and ethical implications of NT would be addressed. I wrote the ethics section of the proposal and described the study I envisioned.

Since speculation about ethics and NT was rampant in 2003, I decided to carry out an empirical study in hopes of generating some grounded knowledge about this topic.

The objective of my study was to determine and analyze NT researchers' views about ethical issues related to their work.

The questionnaire was designed in 2004-05 and administered online from September 2005 to July 2006.

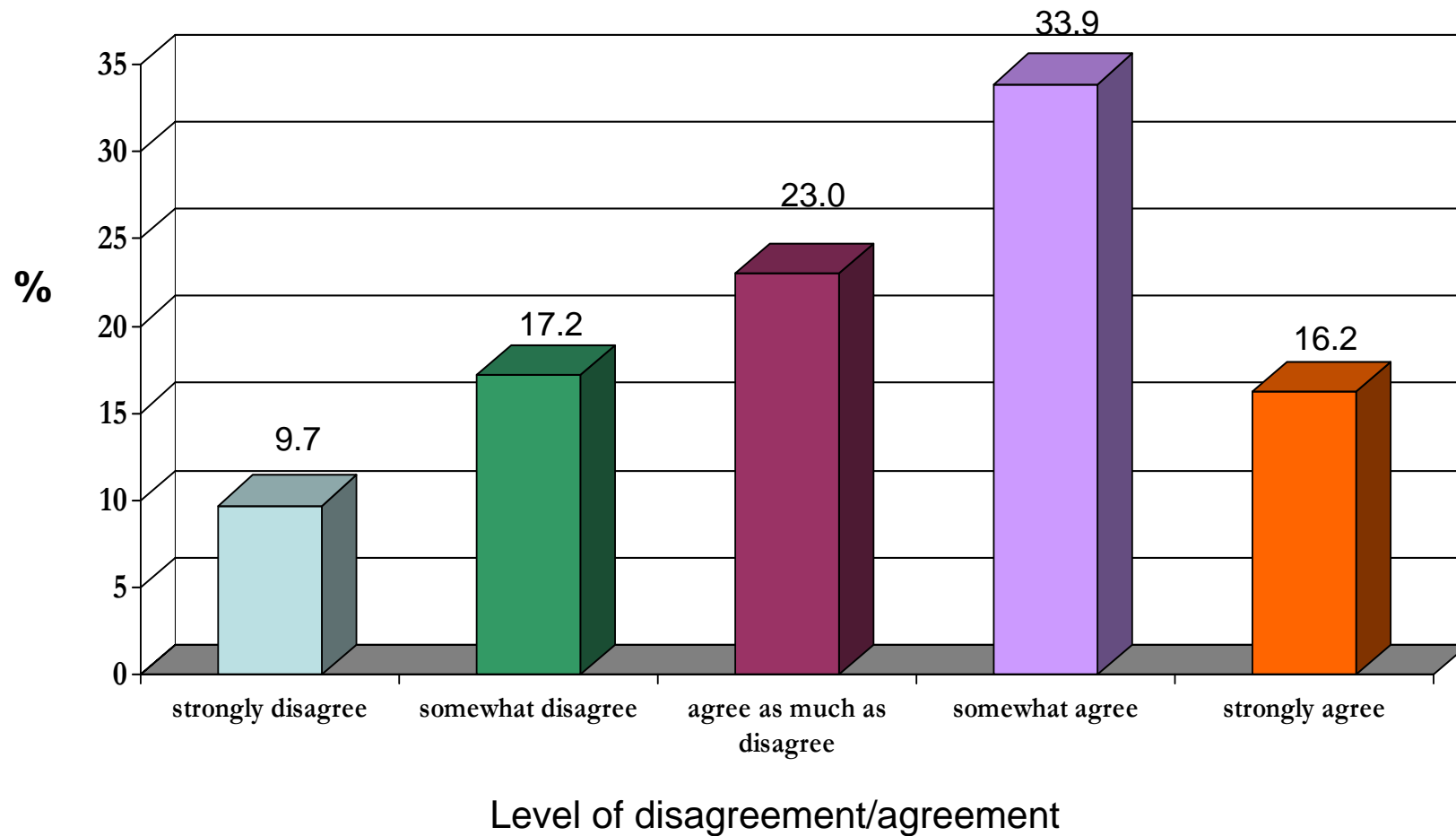
Hopefully, knowing something of NT researchers' views about NT-related ethical issues will be useful background for our discussions at this conference on ethical and societal implications of NBIC convergence, as well as for improving the education of future NT researchers.

Robert McGinn, 2/15/2007

The Survey: Sample

- A. # of Respondents: **1,037** (\cong 21% r.r.)
(\geq 403 grad stud., 128 professors, 109 Ss/Es from industry, 73 post-docs)
- B. Respondents from Cornell, Stanford, Harvard, UW, UMich, UT, GT, UCSB, UNM, PSU, UMinn, NCSU, and Howard NT labs
- C. Robust But Not Random Sample
- D. Gender of Respondents
- | | | |
|------------------|-----|----------|
| male: | 731 | (79.6%) |
| female: | 187 | (20.4%)* |
| blank/no answer: | 119 | |
- *In 2000, women comprised 24.7% of the U.S. science and engineering workforce.
(*Science and Engineering Indicators, 2006*). See <http://www.nsf.gov/statistics/seind06/c3/c3s1.htm#sb3>
- E. Immigration Status of Respondents
- | | | |
|---|-----|---------|
| citizen of USA: | 591 | (64.3%) |
| citizen of some other country: | 266 | (28.9%) |
| permanent resident of USA: | 044 | (04.8%) |
| cit. of other count. + perm. res. of USA: | 014 | (01.5%) |
| dual citizenship: | 004 | (00.4%) |
| blank/no answer: | 118 | |

“There are significant **EIsR2NT**”



Slide 4

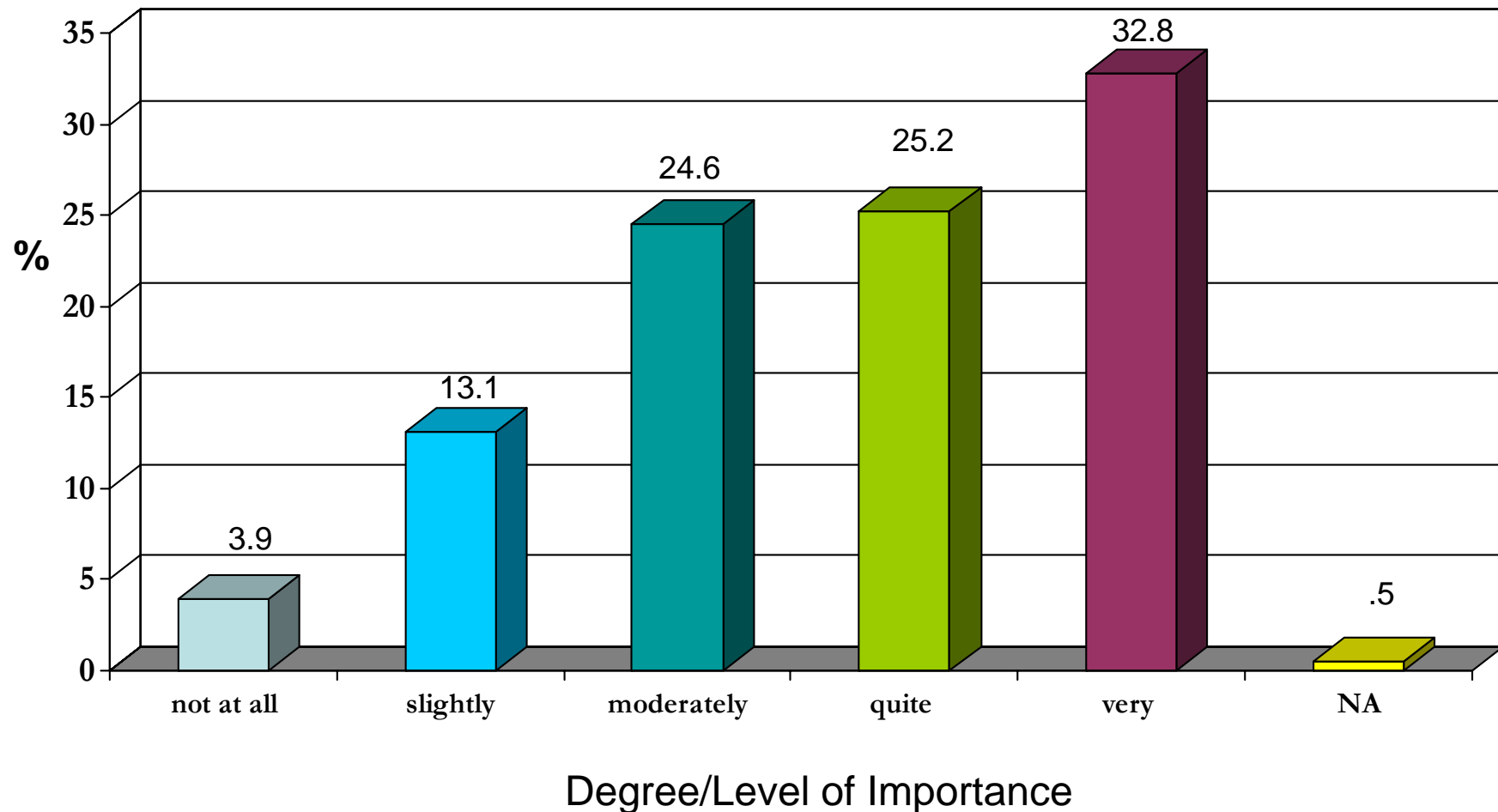
RM3

Note the use of the adjective "significant." The idea here was to get an idea of what percentage of respondents believe that there are NON-TRIVIAL ethical issues related to NT. Note that about HALF believe there are such issues and about A QUARTER do not.

Interestingly, those who STRONGLY DISAGREED that there are significant EIsR2NT were considerably LESS LIKELY to have taken an ethics course than were respondents who STRONGLY AGREED that there are such issues.

Robert McGinn, 12/2/2006

“How important do you believe it is that **EIsR2NT** be considered?”



Slide 5

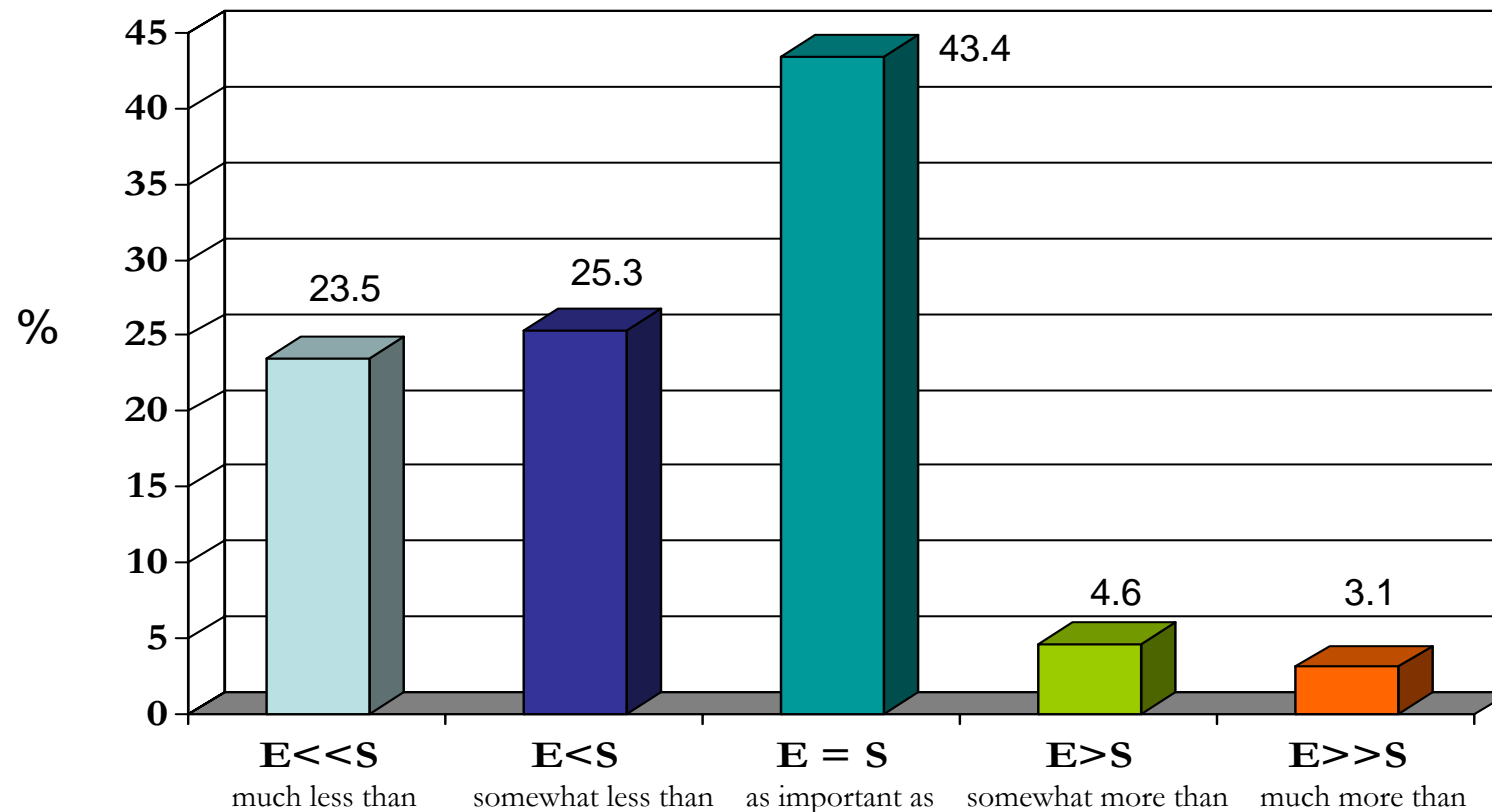
REM4

So, 58% of the respondents believe that it is QUITE or VERY IMPORTANT that such issues be considered, whereas only 17% believe that NOT AT ALL or SLIGHTLY, a ratio of well over 3 to 1.

Most of the 3.9% who replied that it is NOT AT ALL important that EIsR2NT be considered, STRONGLY DISAGREED that there were any significant EIsR2NT, were disproportionately male (compared to the sample as a whole), and had not taken an ethics course of any kind.

Robert McGinn, 2/15/2007

“In your opinion, how does the importance of the **ethical** dimension (E) of the NT field compare with the importance of the **scientific** dimension (S) of the NT field?”



“E” = the importance of the ethical dimension of NT

“S” = the importance of the scientific dimension of NT

Slide 6

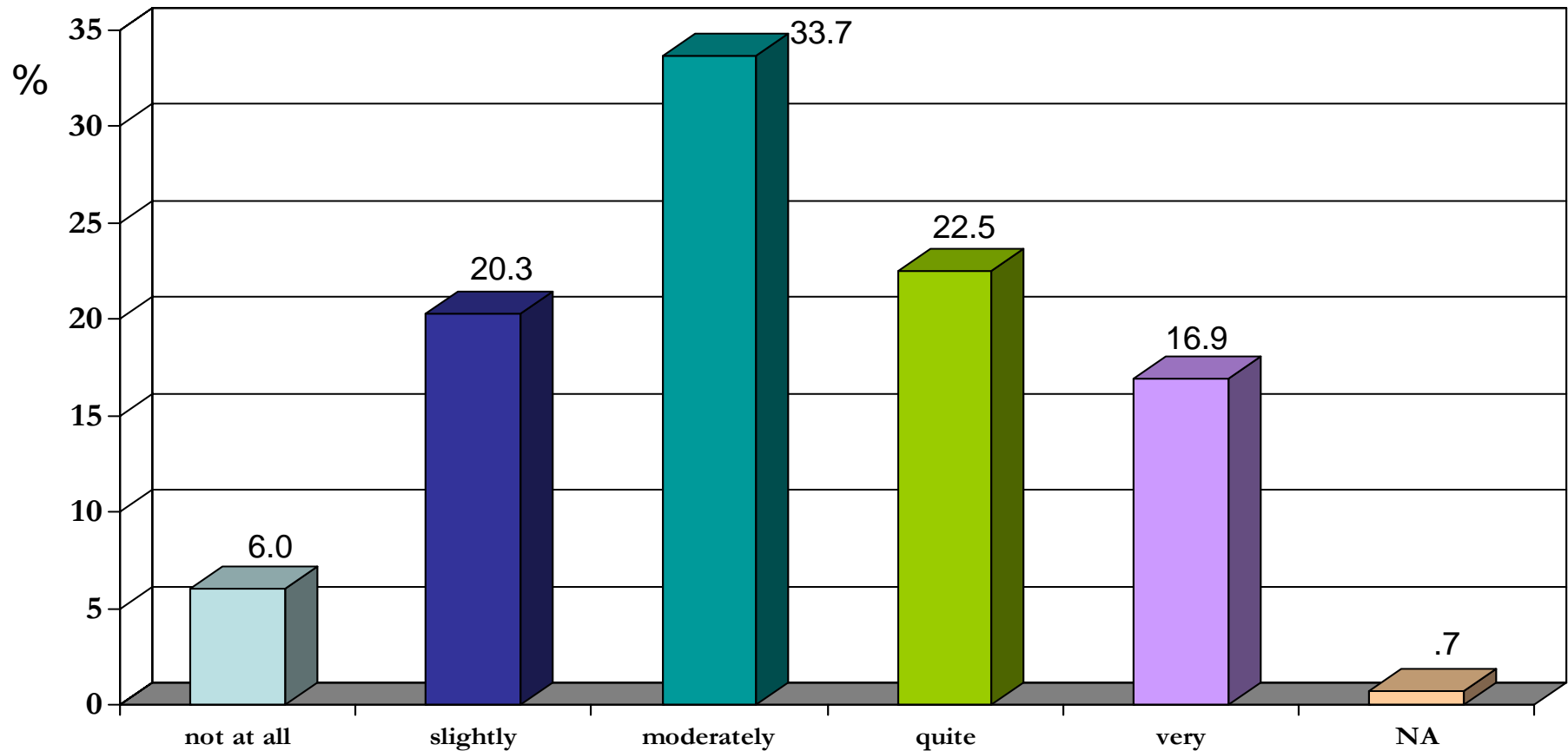
RM5

Thus, a majority of respondents (51.1%) believe that the ethical dimension of NT is either AS IMPORTANT or MORE IMPORTANT than its scientific dimension, while 23.5% believe that E is MUCH LESS IMPORTANT than S.

Given that the scientific dimension of NT is the way most respondents make or will make their living, in my opinion this is a surprising and encouraging result.

Robert McGinn, 12/2/2006

“How interested are you in **EIsR2NT**?”



Level of respondent interest →

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RM6

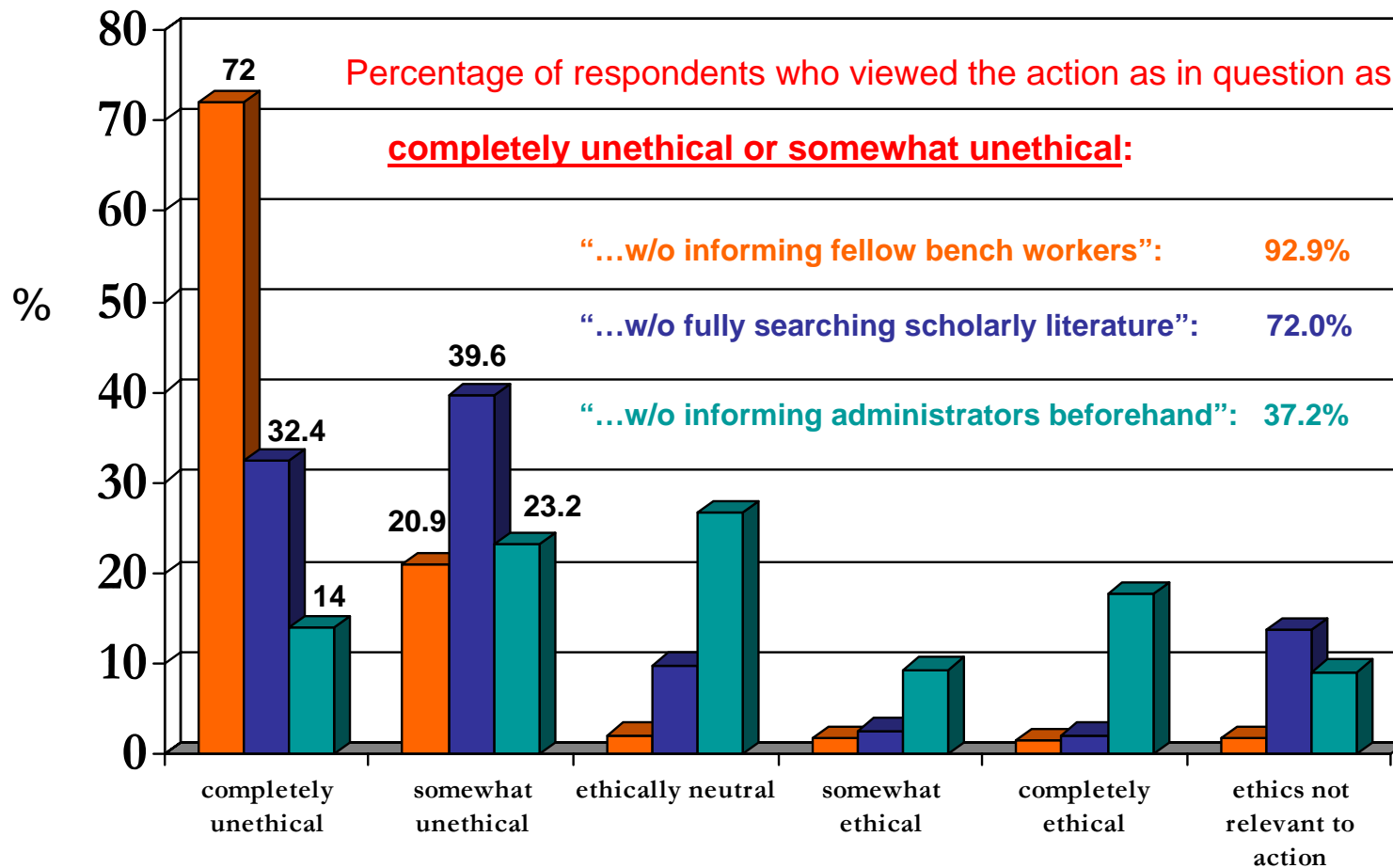
One is struck by the fact that the "VERY" interested response is almost three times the "NOT AT ALL" interested response. Combining the "QUITE" plus "VERY" categories yields the result that almost 4 NT researchers in 10 are seriously interested in the ethical dimension of their work. This is not trivial, especially since (i) these respondents are scientists and engineers, not ethicists, and (ii) the ethical dimension of their work is still rather amorphous, in contrast with the situation today in biotechnology.

Interestingly, a majority of the respondents who were NOT AT ALL INTERESTED in EIsR2NT STRONGLY DISAGREED that there are significant EIsR2NT. Conversely, only 9 respondents who SOMEWHAT OR STRONGLY BELIEVE that EIsR2NT exist were NOT AT ALL INTERESTED in these issues; on the contrary, these believers tended to be MODERATELY, QUITE, OR VERY INTERESTED in them. In other words, among respondents who believe that significant EIsR2NT exist, there was LITTLE INDIFFERENCE to such issues. That underscores how important it is that effort be exerted to persuade the NT research community that there are significant EIsR2NT. If that is done, it is likely that most community members will be interested in them and perhaps be more willing to pay attention to them.

Robert McGinn, 1/1/2007

Three Scenarios: “An experienced NT researcher, never involved in a lab accident, plans to carry out in the lab, for the first time, what s/he realizes is a potentially hazardous procedure, and to do so...

- ...without informing the workers who share her/his bench.”
- ...without fully searching the existing scholarly literature.”
- ...without informing administrators beforehand.”



Slide 8

RM8

It is striking that so many respondents regarded proceeding with the procedure without fully searching the existing scholarly literature and without informing administrators beforehand as either COMPLETELY ETHICAL or as AN ACTION TO WHICH ETHICS IS NOT RELEVANT.

It would appear that for these respondents, failure to take precautionary steps only counts as unethical if there is a rather DIRECT RISK OF HARM, as there is when fellow lab workers are not informed of what is to take place. The less tightly coupled (a) the failure to take precaution and (b) the possible harm involved, the less respondents view the situation as ethically problematic or even as ethically relevant. That suggests the need for emphasizing to NT researchers the ethical significance of creating a risk of harm, even if only by omission (of precautionary action). In short, in my opinion, NT practitioners could use some discussion of the ethics of precaution.

Robert McGinn, 2/15/2007

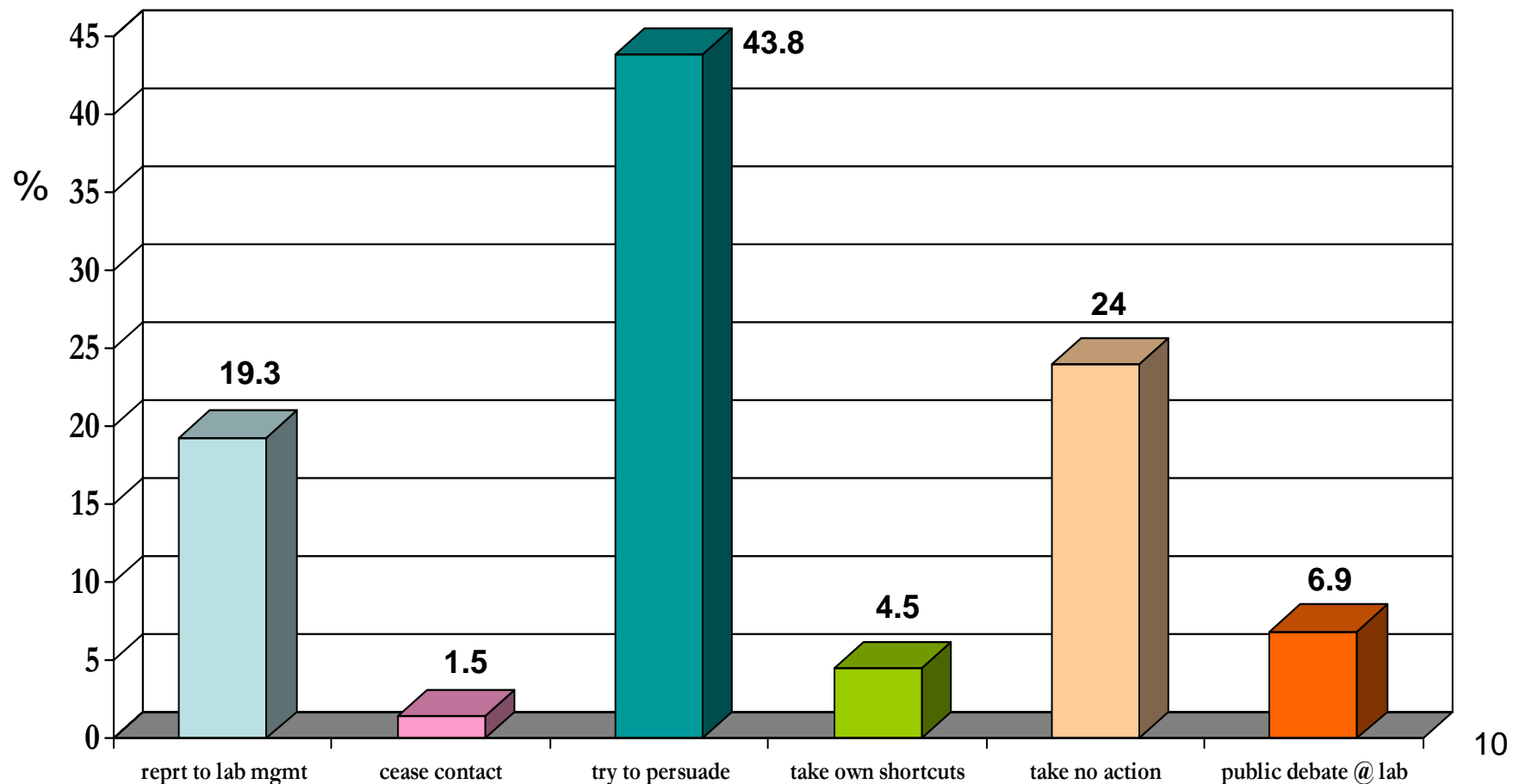
Scenario: “For several weeks, a nanotech lab researcher has been taking a relatively safe, time-saving **shortcut** in doing her/his work. This shortcut clearly violates published laboratory procedures. So far, no unfortunate results have occurred because of this behavior. Other lab users know that s/he is taking this shortcut.”

The respondent was then asked the following question:

“Which of the following do you think would be the two most likely responses to this situation by users in your nanotech lab?”

1. Users would **report** the individual **to lab management**.
2. Users would **cease having professional contact** with the individual.
3. Users would approach the individual and **try to persuade her/him to stop taking the shortcut**.
4. Users would **start taking rule-violating shortcuts of their own**.
5. Users would **take no action** and the situation would continue unchanged.
6. Users would **make this situation a matter of public debate at the lab**.

Distribution of Reactions Respondents Believe the Most Likely in their Labs to a Researcher Taking a Prohibited Shortcut



Slide 10

RM10

Of the 24% who chose "take no action," 78.4% were U.S. citizens, while 17.9% were citizens of another country. In contrast, 64.3% of the sample as a whole were U.S. citizens and 28.9% were citizens of other countries.

Robert McGinn, 10/29/2006

Characteristics of the 24% of respondents who chose option 5 -- “Take No Action” -- as the most likely response to a shortcutter in their labs:

1. 78.8% were US citizens and 17.5% were citizens of another country.

(In contrast, 64.3% of the sample as a whole were US citizens and 28.9% were citizens of another country.)

2. Thus, US citizens were disproportionately highly represented among respondents who chose the passive “take no action” option.

3. **Comment:** NT laboratory cultures are apt to differ from site to site. To the extent that a particular NT lab has a *laissez-faire culture*, it threatens lab safety and increases the risk of harm to those who would be affected if an unfortunate accident took place. This strongly suggests that top laboratory managers have an ethical responsibility to actively promote a **safety CULTURE** in their facilities.

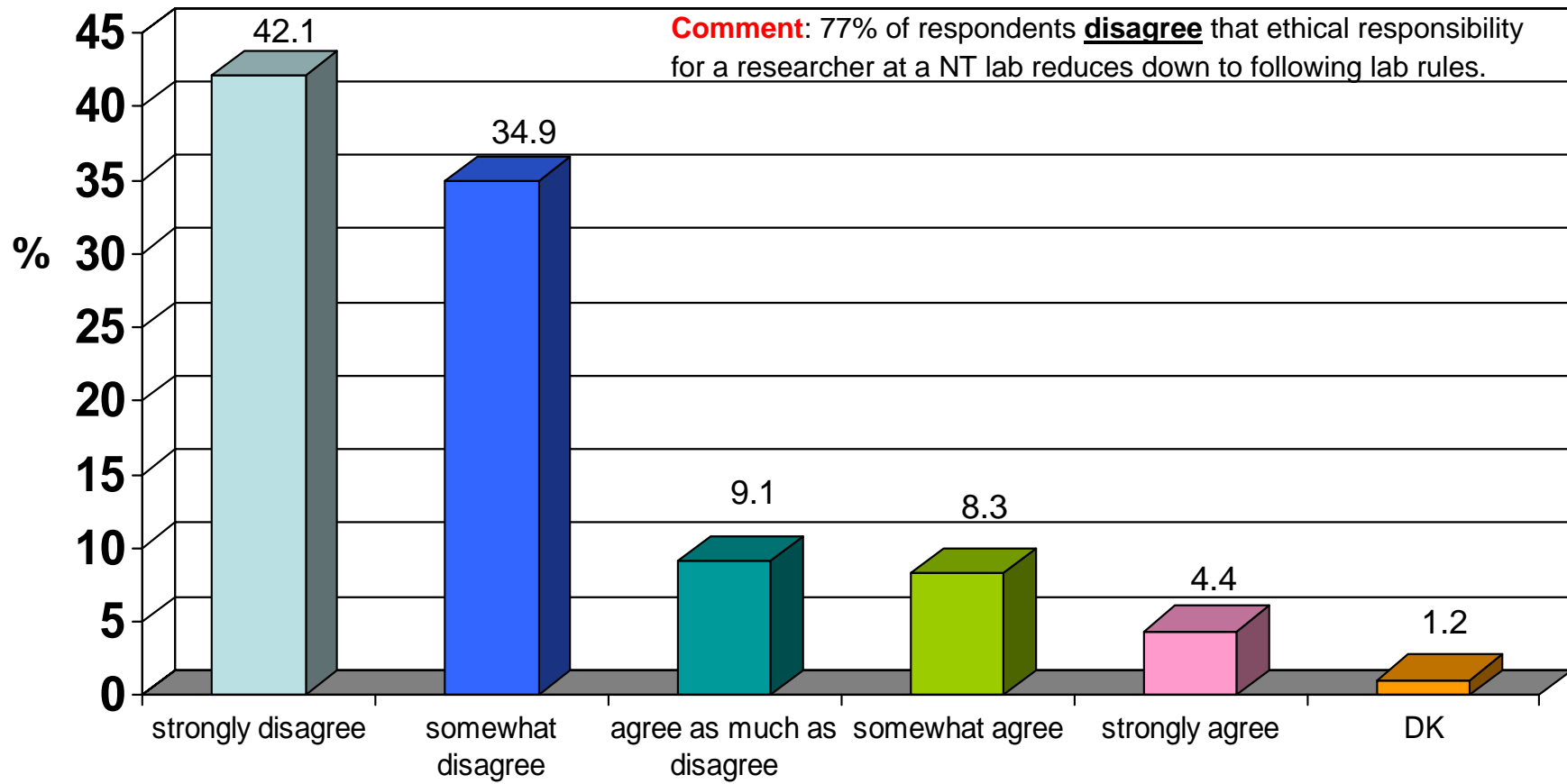
(Replies to one questionnaire item showed that 81.6% of respondents viewed failure by top lab managers to actively promote a safety culture as somewhat or completely unethical.)

Respondent % by site that gave “take no action” as most likely response at their lab to shortcutting

NNIN Site	%
• Site1	24.0
• Site2	25.2
• Site3	28.9
• GeorgiaTech	13.7
• Site5	21.6
• Penn State	13.0
• Site7	22.6
• Site8	29.0
• Site9	37.7
• Site10	20.0
• Site11	25.9
• Site12	10.0*
• Site13	18.6

Overall percentage of “take no action” responses: 24%

“The only ethical responsibility of a researcher at a NT lab is to follow laboratory rules.”



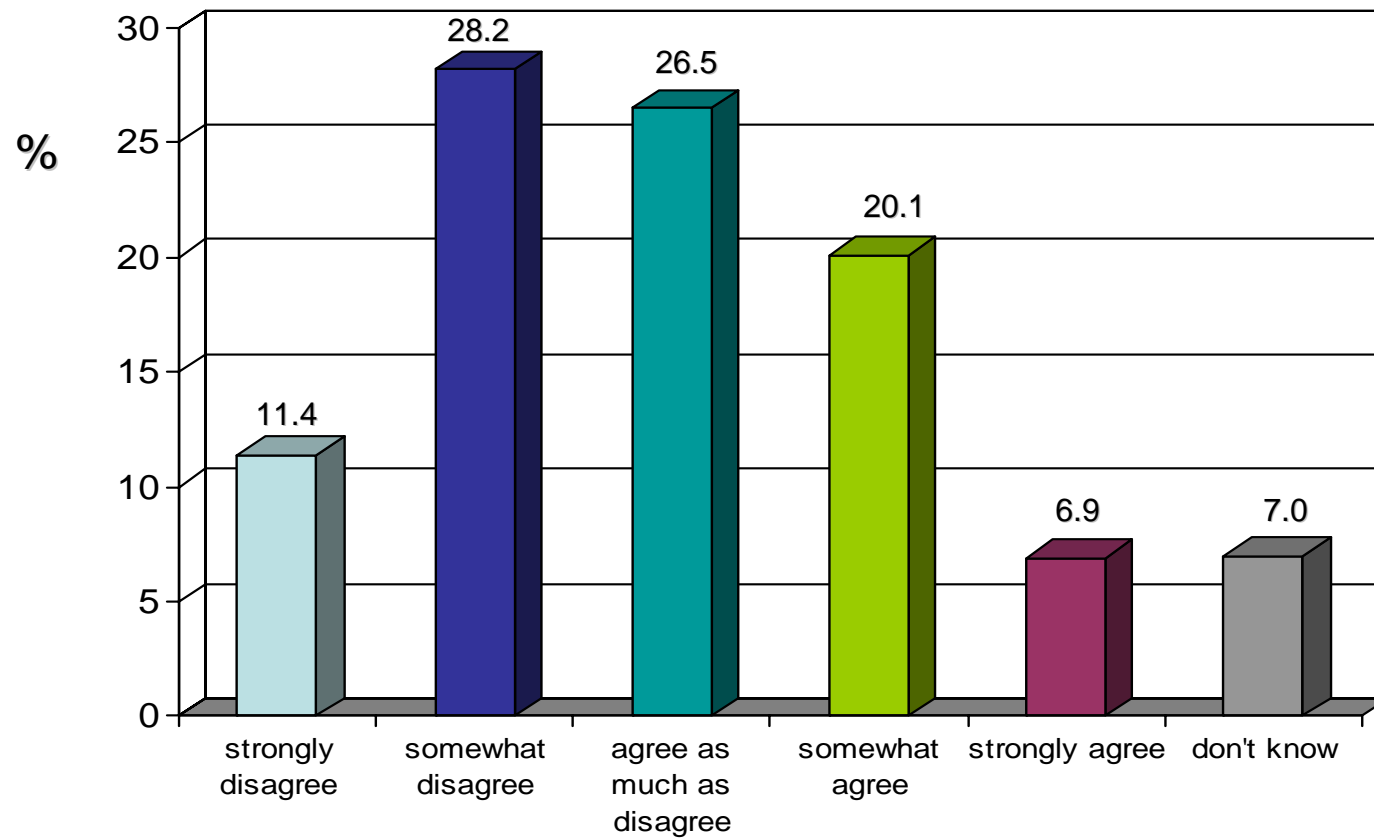
Slide 13

RM11

Note: of the 44 respondents (4.4%) who strongly agree with this claim, 38 indicated their citizenship. Of these, 19 or 50% were citizens of another country: 16 were citizens of another country, 2 were citizens of another country AND of the U.S., and 1 was a citizen of another country and a permanent resident of the U.S. Of these 19, 14 indicated that they were of "Asian" ethnicity, 3 indicated that they were "white," and 2 did not indicate their ethnicity. In other words, of those who indicated their ethnicity, 14 of 17 or 82.4% were of Asian ethnicity. For the sample as a whole, 25.5% of respondents indicated Asian ethnicity. IMPORTANT CAUTIONARY NOTE: While this finding is suggestive, this group of 38 respondents who STRONGLY AGREED and indicated their CITIZENSHIP, is too small for one to be able to assert with confidence any conclusion about the views of respondents re ethical responsibility being reducible to following laboratory rules as a function of their ethnicities/cultural backgrounds.

Robert McGinn, 2/15/2007

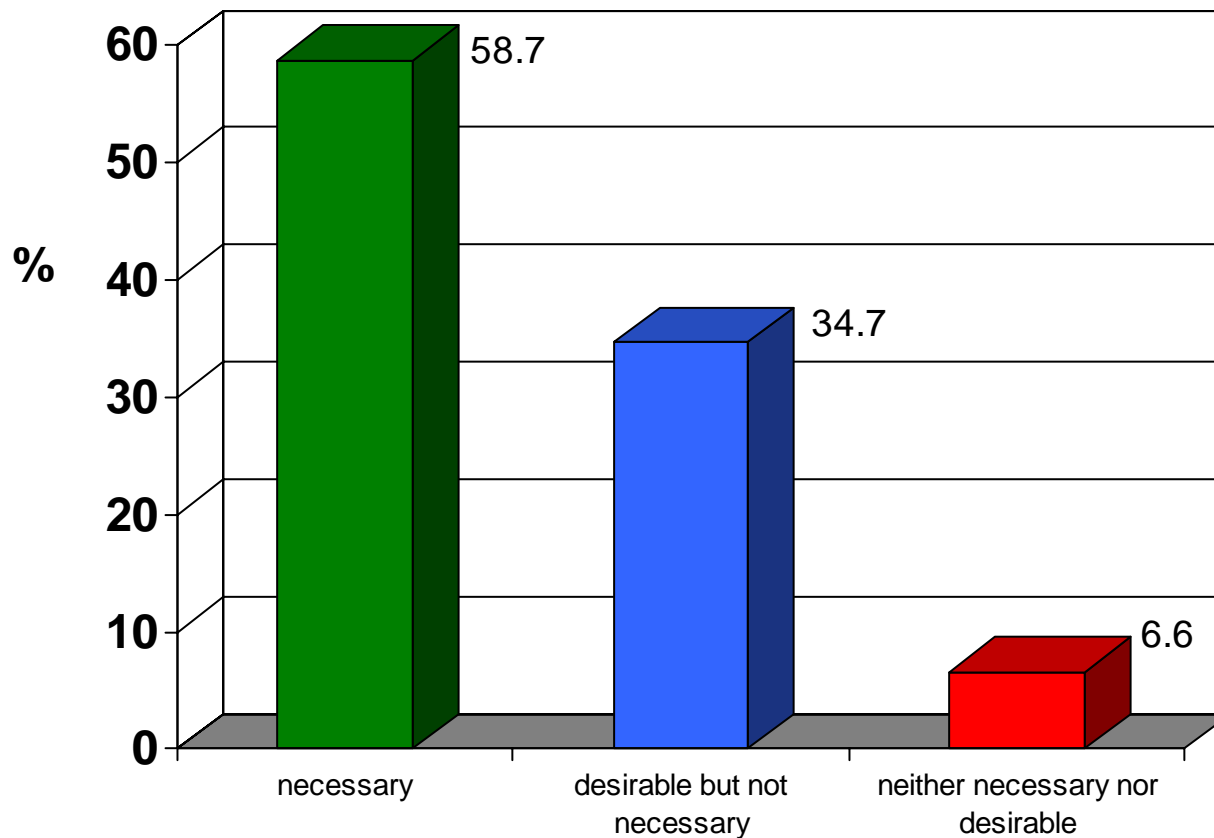
“Nanotech researchers are willing and able to regulate themselves.”



“Which of the following three statements do you agree with the most?”

- “It is **...necessary...**
- ...desirable but not necessary...**
- ...neither necessary nor desirable...**

...to have clear ethical guidelines for the conduct of nanotech research.”



Who are the respondents in this 6.6%?

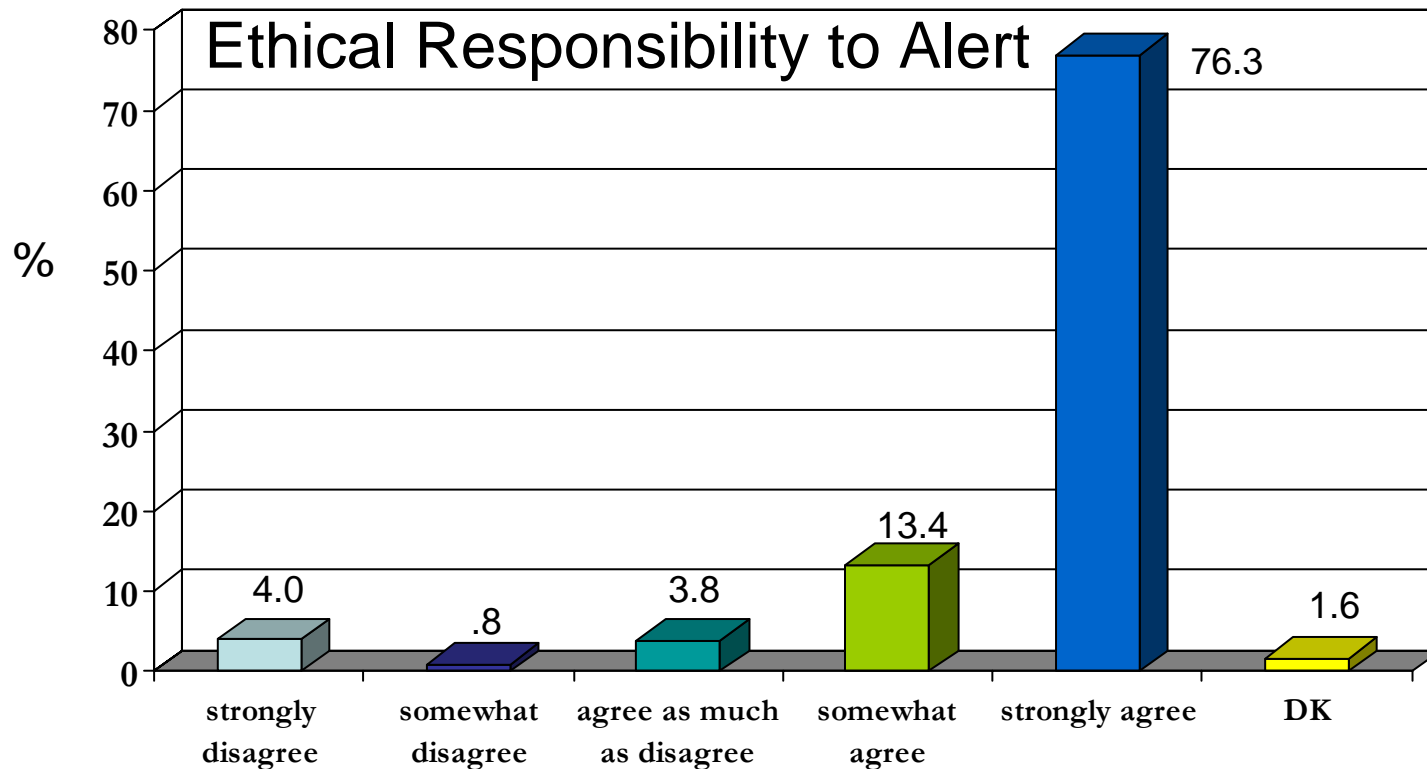
Slide 15

REM12

It is striking that almost three fifths of the respondents believe that it is necessary to have ethical guidelines for the responsible conduct of nanotech research and that only 1 in 16 respondents regard it as neither necessary nor desirable to have such guidelines. Clearly, this sample of nanotech researchers is not averse to the development of such guidelines and would not regard their promulgation as an intrusion into or interference with their work. On the contrary, most would welcome it and appear to think it needed.

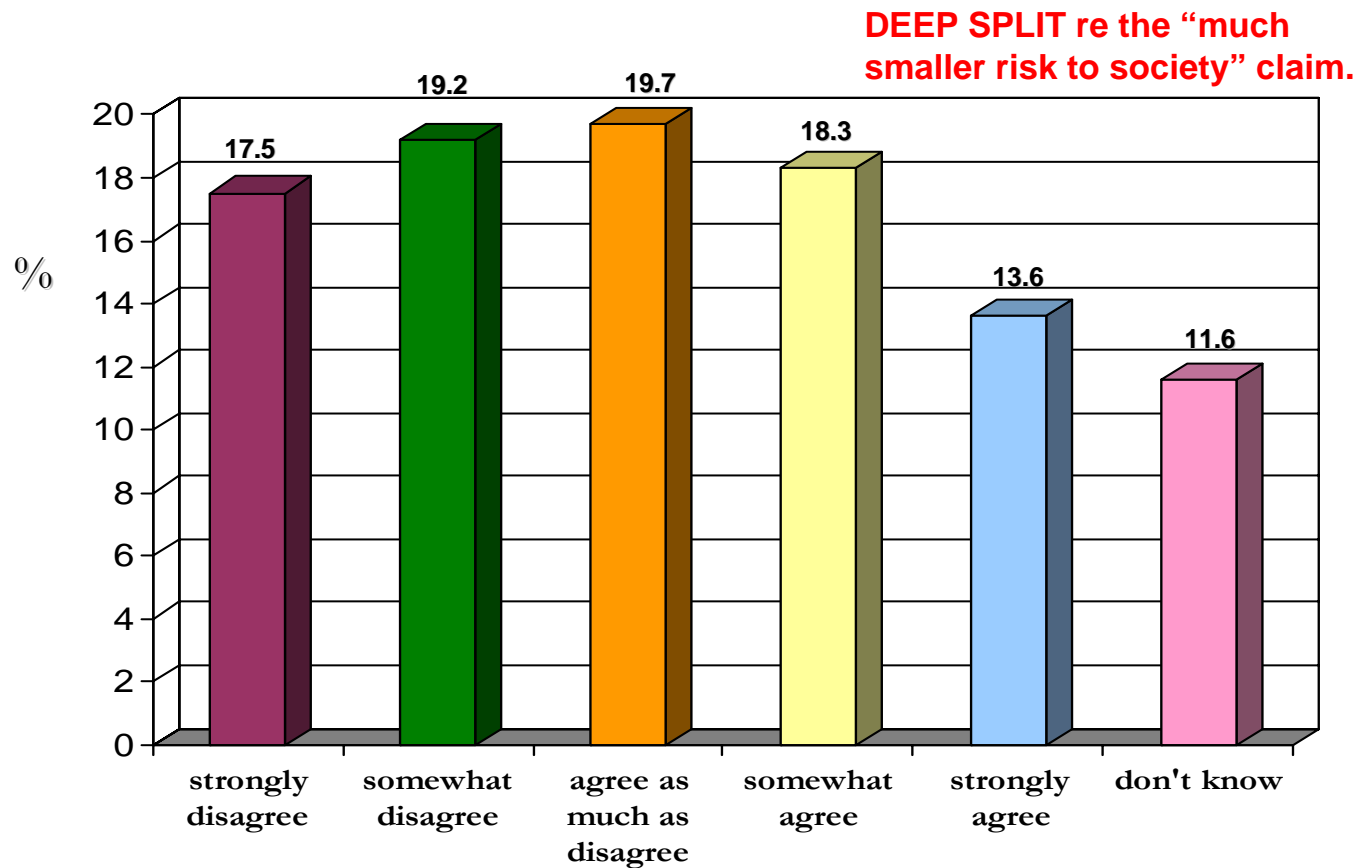
Robert McGinn, 1/1/2007

“If a NT researcher has reason to believe that her/his work will be applied in society so as to pose a significant harm to human beings, s/he has an ethical responsibility to alert appropriate parties to the potential dangers.”



Level of agreement →

“Work on **nanoscale materials, devices, and systems** with the potential to be turned into **weapons** poses a **much smaller risk to society** than does work on **biological agents** with the potential to be turned into **weapons**.”



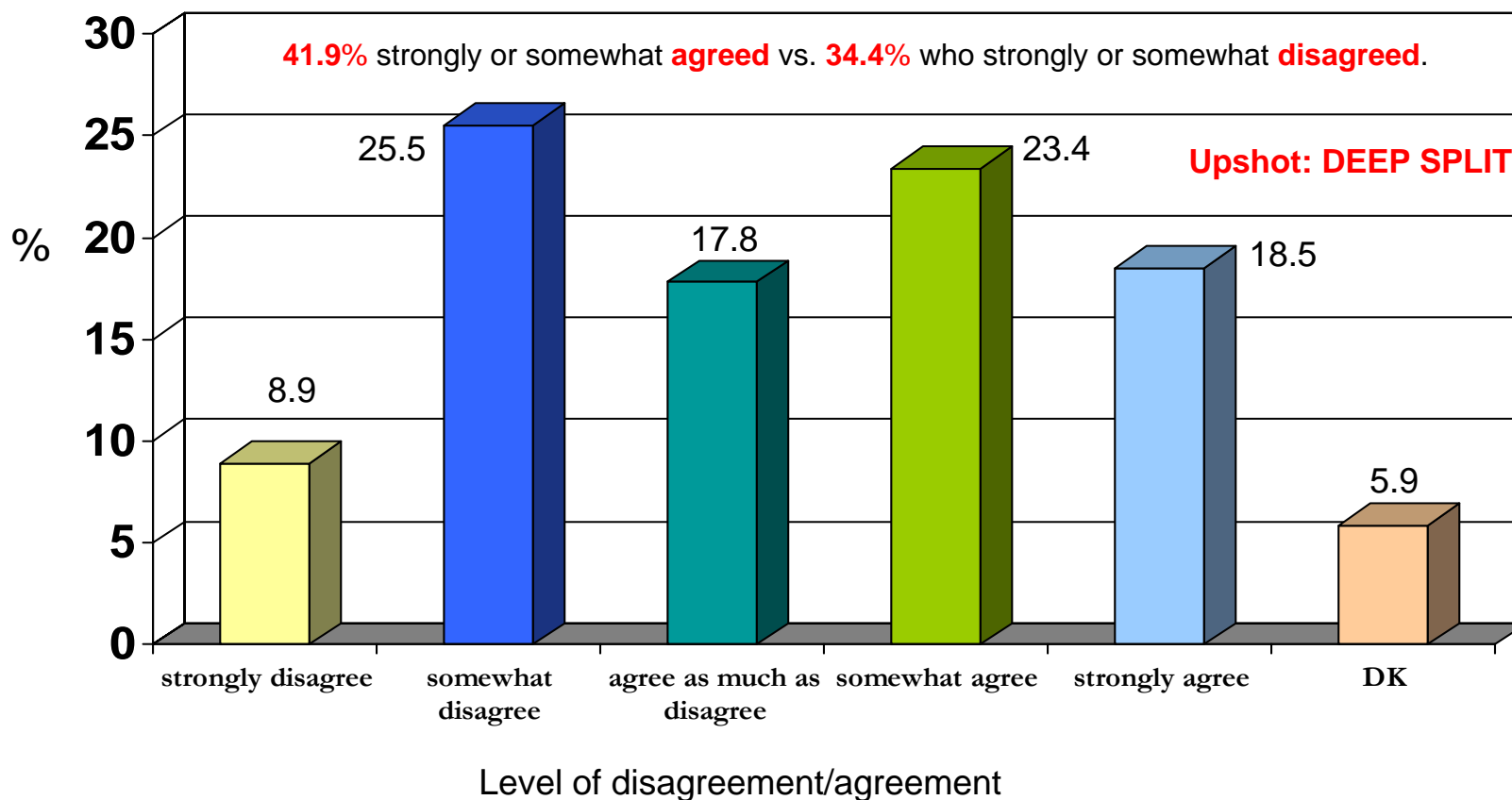
Slide 17

REM15 More respondents disagree with this "much smaller risk to society" claim than agree with it, more strongly disagree than strongly agree, and a significant percentage claim not to know. At least it can be said that on the whole the respondents don't trivialize the risk to society posed by nano- materials, -devices, and -systems w/ the potential to be turned into weapons. Indeed, more than a third seem to view the nano products in question as being either only a little less risky, as risky, or more risky than weaponizable biological agents.

Robert McGinn, 12/29/2006

Human-Implantable Nanodevices (HINDs) I:

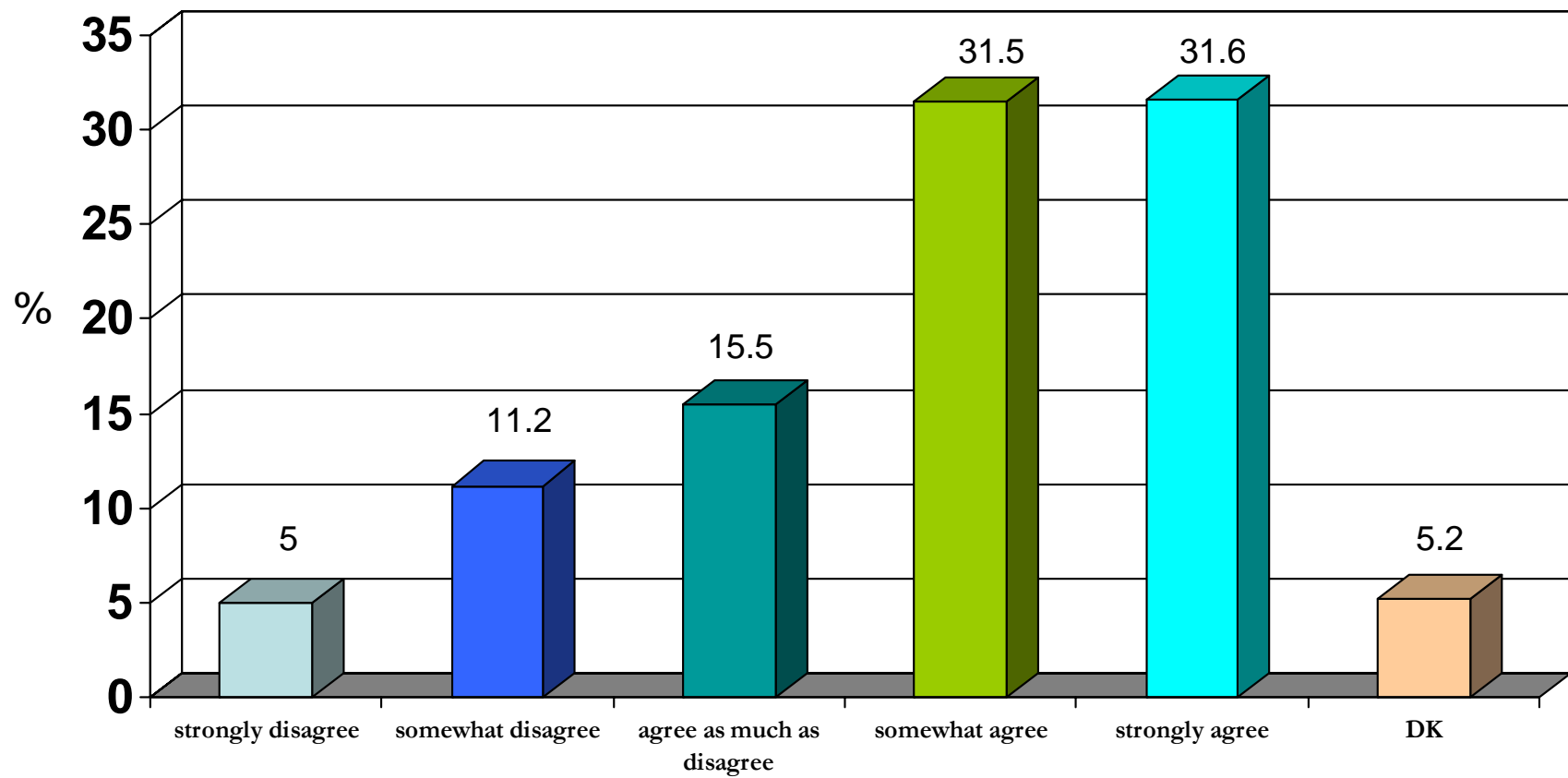
“Biomedical human-implantable nanodevices raise no more ethical issues than human-implantable devices used in the past and at present.”



HINDs II:

“The convergence of work in NT, biotechnology, information science, and cognitive science will eventually result in the development of human-implantable nanodevices that raise significant ethical issues.”

“NBIC convergence”



Slide 19

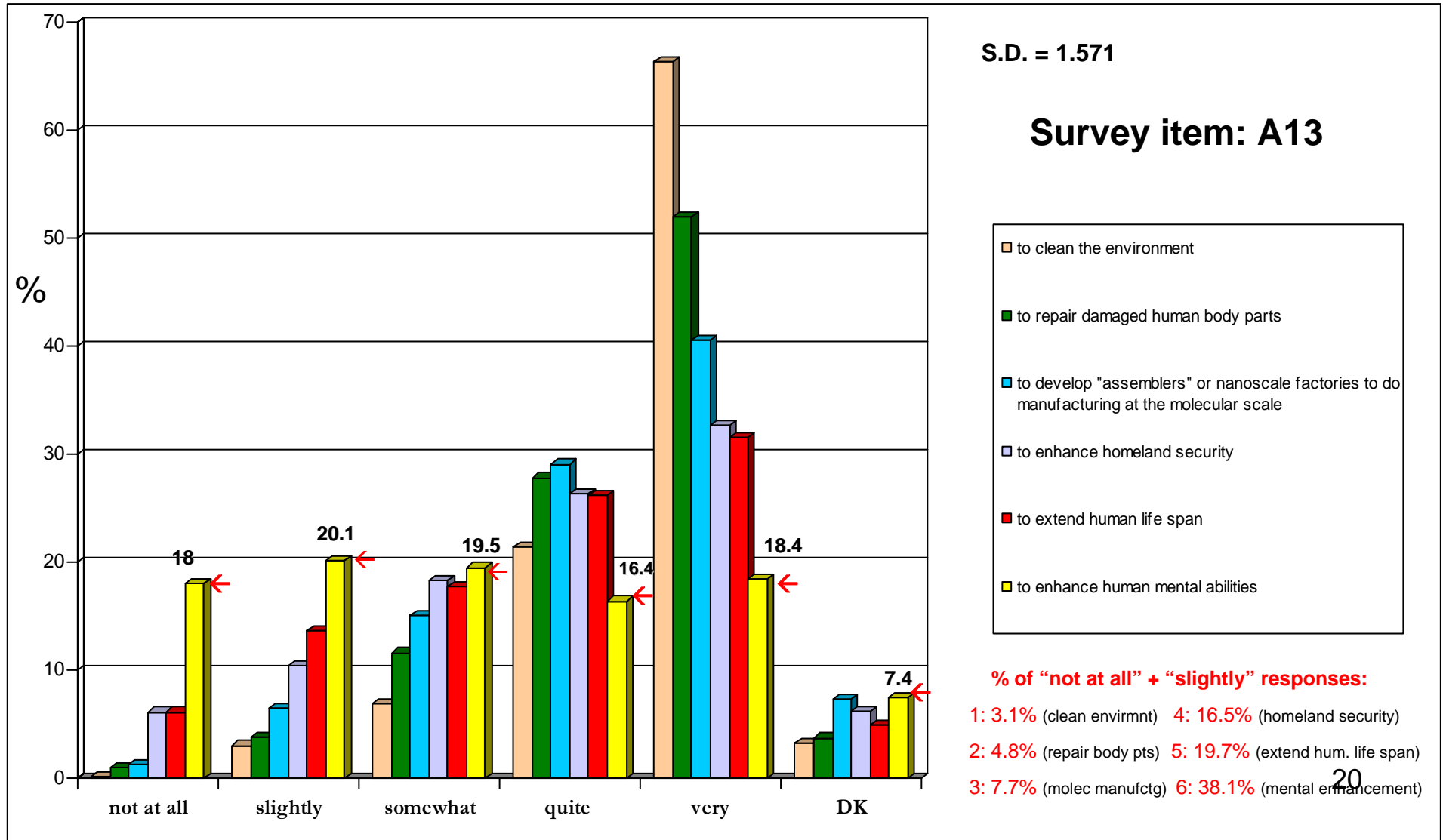
RM14

"NBIC Convergence" refers to the projected convergence of four streams of research: in nanotechnology, biotechnology, information science/technology, and cognitive science. It is expected that in the future some HINDs will be based on/emerge from NBIC convergence.

Of those with views other than "DK," 66.6% somewhat or strongly agreed that NBIC devices will raise significant ethical issues, while only 17.1% somewhat or strongly disagreed.

Robert McGinn, 1/1/2007

How morally acceptable to respondents are each of the following 6 possible NT-based project goals?



Slide 20

RM20

Note the deep split on the NT project goal of INCREASING HUMAN MENTAL ABILITIES: 38.1% find this goal not at all or slightly morally acceptable, while 34.8% find it quite or very morally acceptable. Note also that no response category received more than 20.1% of the responses.

Compare the dissensus on moral acceptability re INCREASING HUMAN MENTAL ABILITIES with the consensus about the moral acceptability of the goals TO CLEAN THE ENVIRONMENT and TO REPAIR DAMAGED HUMAN BODY PARTS. Respondent views exhibit significant differentiation as a function of the specific goals and, on the whole, seem to parallel the views of the general public on the relative moral acceptability of therapeutic vs. enhancement uses of applications of innovations in biotechnology.

Robert McGinn, 2/15/2007

The NT Project Goal of 'Enhancing Human Mental Abilities'

As far as the likelihood of the most controversial of the 6 possible goals for NT listed on the previous slide, viz., the goal of “enhancing human mental abilities,”...

→ ...270 of the 900 respondents (30%) said that NT-based projects with this goal were “quite” or “very” likely to be pursued in the next 25 years.

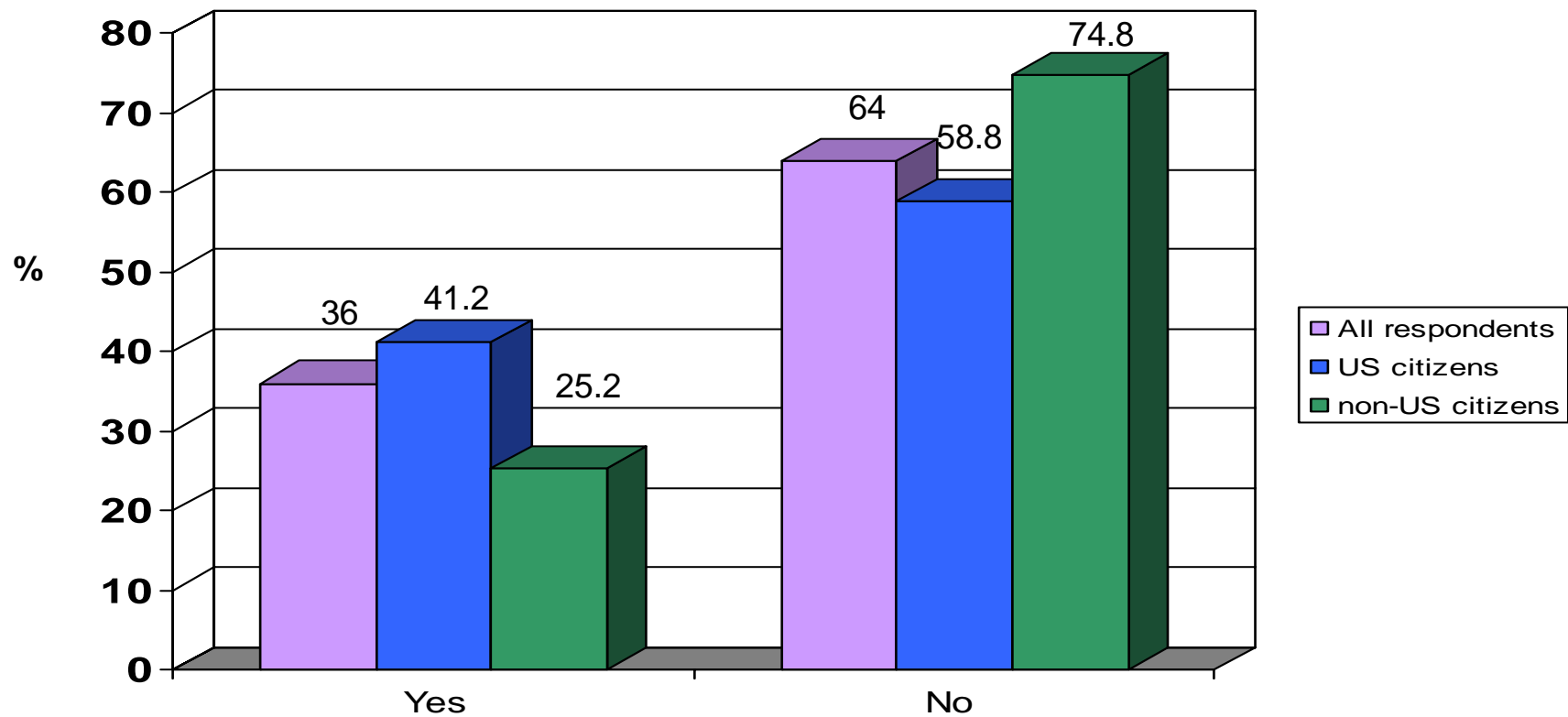
and

→ ...73 of these 270 (27%) judged these projects “not at all” or “slightly” morally acceptable.

So, for this group, there is considerable ‘cognitive dissonance’ over this possible goal for NT: i.e., that which they deem highly likely to be pursued they also find quite morally unacceptable.

Many of these moral qualms seem to be rooted, at least partly, in safety concerns. Of those who deem this possible project goal to be “not at all” or “slightly” morally acceptable, 53.5% believe the related projects will prove to be “not at all” or “slightly” safe for humans, while only 5.6% believe they will prove to be “quite” or “very” safe. Thus, a good number of NNIN researchers see this NT-related project goal as both highly likely to be pursued and highly likely to raise safety/health concerns. Such practitioners could face difficult ethical issues re such project goals in the future.

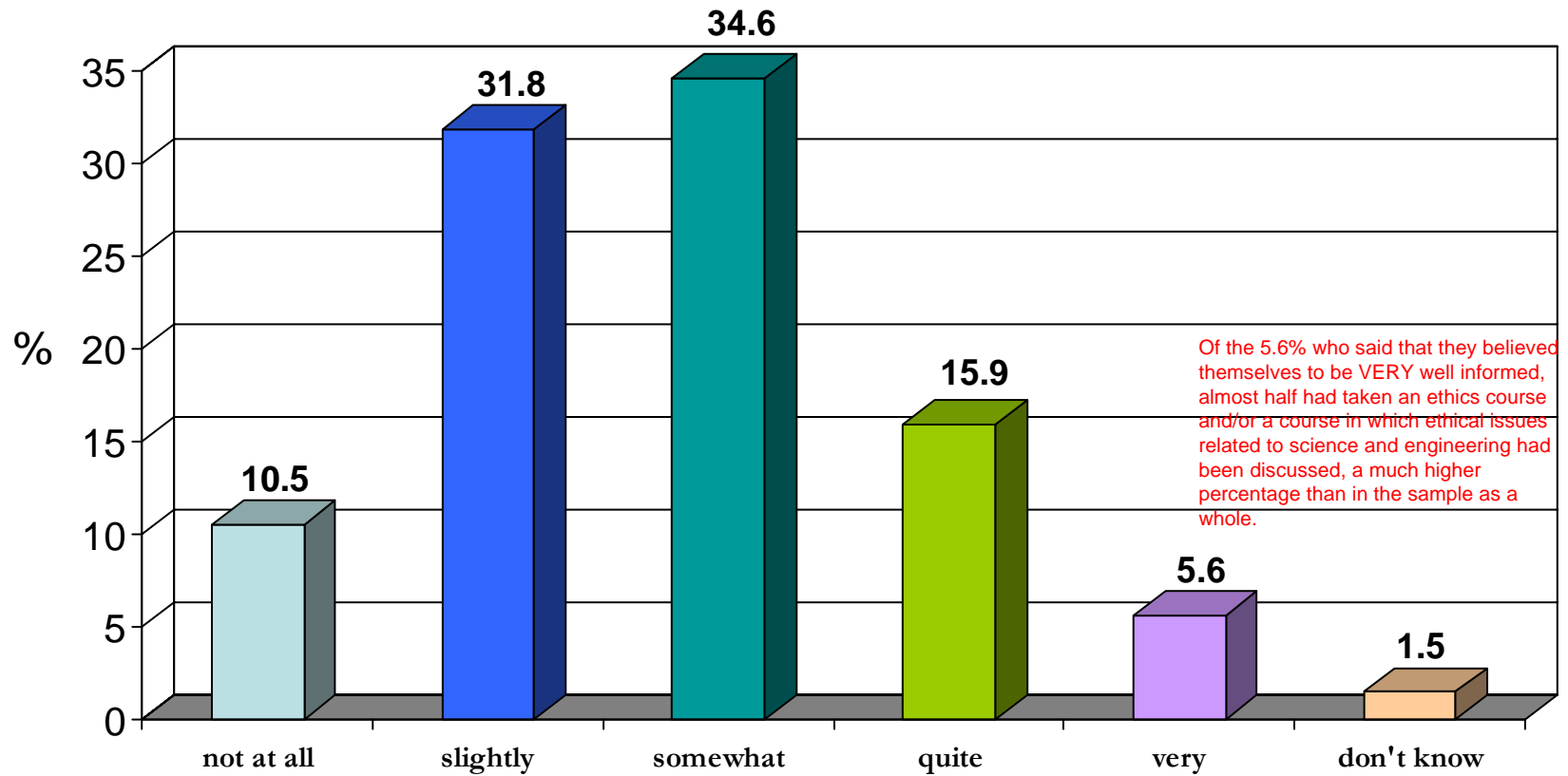
“Did you ever take a course in which ethical issues closely related to science, technology, and/or engineering were discussed?”



“Yes” = have had a course w/ such discussion.

“No” = have never had a course w/ such discussion.

“How well informed do you believe you are about EIsR2NT?”



How well informed respondent believes s/he is about EIsR2NT →

Slide 23

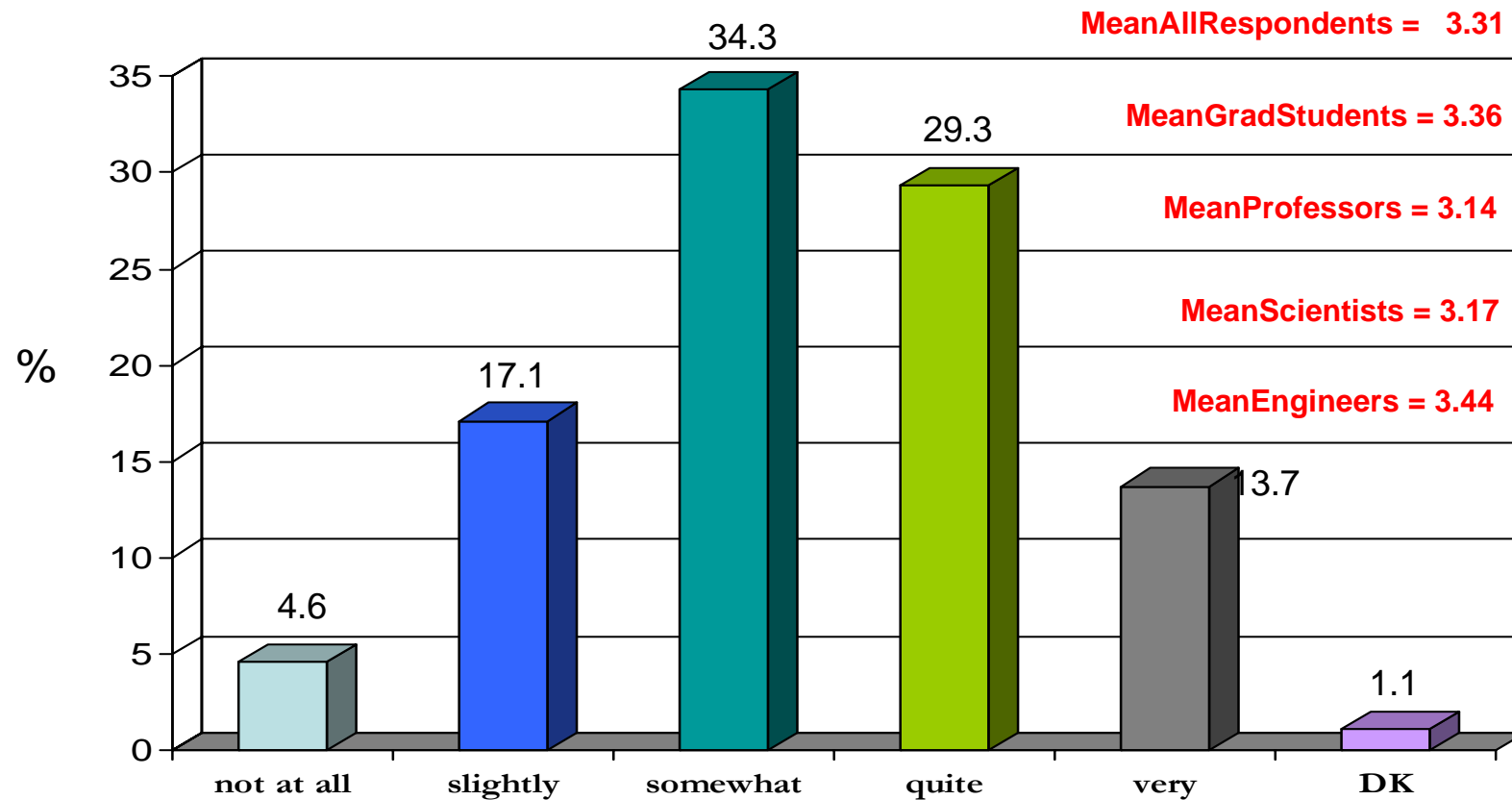
RM23

Note that the ratio of {'not at all' + 'slightly'} to {'quite' + 'very'} is about two to one (42.3 to 21.5). Clearly, on average respondents do not feel particularly well informed about EIsR2NT.

Of the 5.6% who said that they believed themselves to be VERY well informed, almost half had taken an ethics course and/or a course in which ethical issues related to science and engineering had been discussed, a much higher percentage than in the sample as a whole.

Robert McGinn, 12/2/2006

“How willing are you to spend some time learning about EIsR2NT?”



Increasing levels of willingness →

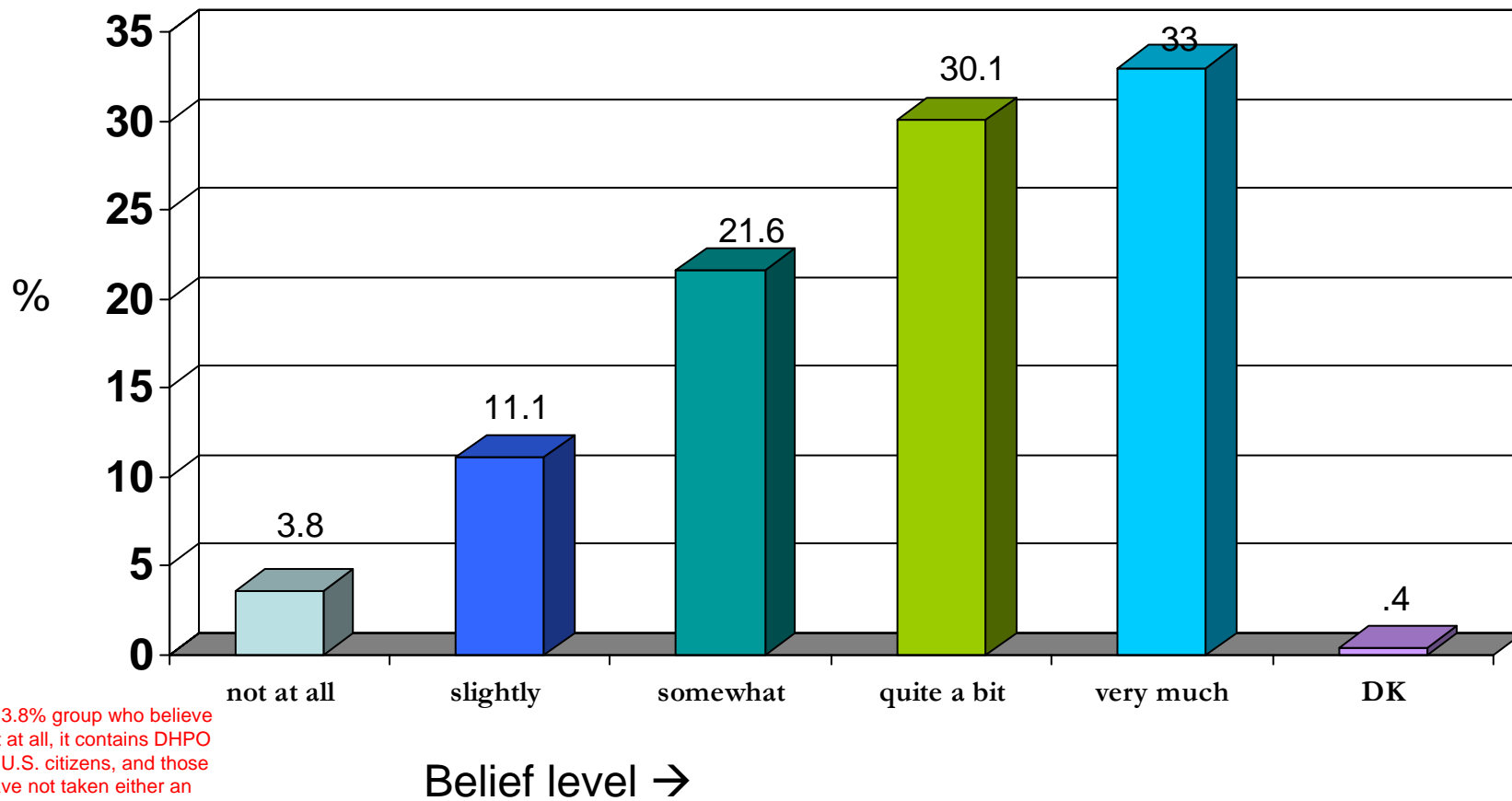
Slide 24

REM18 Looking at the 4.6% of respondents who stated that they are "not at all" willing to spend some time learning about EIRs2NT, it turns out that, in light of the percentages they make up of the entire sample, scientists, U.S. citizens, and males are disproportionately OVERREPRESENTED in the "not at all willing to spend some time learning about EIRs2NT" group. Citizens of foreign countries, females, and graduate students are disproportionately UNDERREPRESENTED in this group. For example, while females comprised 20.4% of all respondents that indicated their gender, they comprised only 2.4% of the "not all willing to spend some time learning about EIRs2NT" group!

Looking at the 13.7% who were VERY willing to spend time learning about EIRs2NT, almost half (48.4%) had taken a course in which ethical issues related to science and engineering were discussed and 43.2% had taken an ethics course. It would appear that taking a course in which ethical issues related to science and engineering are discussed is a factor that is conducive to respondents being very willing to spend time studying about EIRs2NT.

Robert McGinn, 12/2/2006

“How much do you believe that study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists?”



Re the 3.8% group who believe this not at all, it contains DHPO males, U.S. citizens, and those who have not taken either an ethics course or a course in which ethical issues related to issues of S, E, and T were discussed.

Slide 25

RM22

Here the ratio of {'quite a bit' + 'very much'} to {'not at all' + 'slightly'} is 4.23 (63.1 to 14.9), representing a clear majority quite strongly in favor of including such study in the education of future engineers and scientists.

Regarding the 3.8% of respondents who do NOT AT ALL believe that such study should become a standard part of the education of future engineers and scientists, it contains disproportionately very high percentages of MALES, U.S. CITIZENS, THOSE WHO HAVE NEVER TAKEN AN ETHICS COURSE, and THOSE WHO HAVE NEVER TAKEN A COURSE IN WHICH ETHICAL ISSUES RELATED TO SCIENCE AND ENGINEERING WERE DISCUSSED.

Robert McGinn, 12/2/2006

Do NNIN researchers “take ethical issues related to NT seriously?”

The survey did **not** ask this question directly. An **indirect** approach is both feasible and preferable.

First, let us define 9 simple functions, each corresponding to a question posed in the survey:

- | | | |
|---|-------|---------|
| TES1: To what degree to you agree or disagree that significant EIsR2NT exist ? | [1,5] | 4-5 → 1 |
| TES2: How interested are you in EIsR2NT? | [1,5] | 3-5 → 1 |
| TES3: How important do you believe it is that EIsR2NT be considered? | [1,5] | 3-5 → 1 |
| TES4: How does the importance of ethical dimension of NT field compare w/ its scientific dim.? | [1,5] | 2-5 → 1 |
| TES5: To what degree do you agree or disagree that NT researchers should always strive to anticipate ethical issues that may arise from future applications of their work? | [1,5] | 4-5 → 1 |
| TES6: To what degree do you agree or disagree that if a NT researcher has reason to believe that her/his work will be applied in society so as to pose a risk of significant harm to humans, s/he has an ethical responsibility to alert appropriate authorities to the potential dangers? | [1,5] | 4-5 → 1 |
| TES7: Having clear ethical guidelines for the conduct of NT research... | [1,3] | 1-2 → 1 |
| TES8: How willing are you to spend some time in the future learning about EIsR2NT ? | [1,5] | 3-5 → 1 |
| TES9: How much do you believe that study of ethical issues related to science and engineering should become a standard part of the education of future engineers and scientists? | [1,5] | 4-5 → 1 |

With this in mind, we define a new master dependent variable, the **taking-ethical-issues-related-to-NT-seriously** variable:

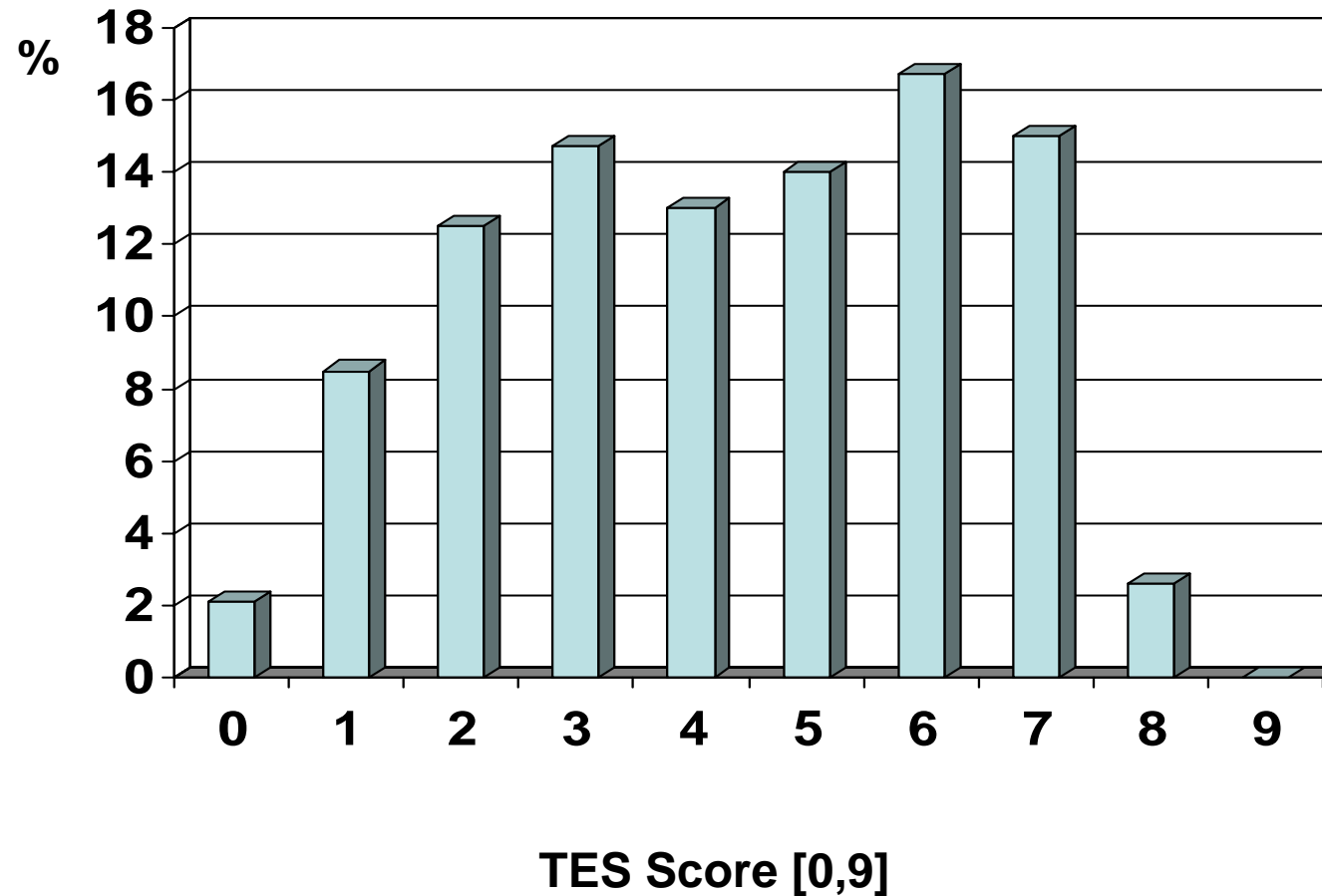
$$\text{TES} = \text{TES1} + \text{TES2} + \text{TES3} + \text{TES4} + \text{TES5} + \text{TES6} + \text{TES7} + \text{TES8} + \text{TES9}$$

[0,9] [0,1] [0,1] [0,1] [0,1] [0,1] [0,1] [0,1] [0,1] [0,1]

So, each respondent gets a **TES score of between 0 and 9**, depending on her/his answers to the 9 questions.

Distribution of TES Scores of Respondents Who Answered All 9 Questions

N = 815



Of respondents who answered all 9 TES questions, % at each site with TES scores ≥ 6 and ≤ 3

	% ≥ 6	Mean TES	% ≤ 3
• Site1	32.9		39.1
• Site2	28.4		41.9
• Site3	39.1		33.3
• Site4	32.4		35.1
• Site5	32.7		34.6
• Site6	63.9	5.33	19.4
• Site7	31.9		42.0
• Site8	19.6	3.67	54.9
• Site9	27.0		40.5
• Site10	28.9		33.3
• Site11	34.7		38.8
• Site12	58.6		20.7
• Site13	35.1		29.7

% of <u>all respondents at all sites</u> who achieved a TES score of ≥ 6 :		34.3%
	≤ 3 :	37.4%
Mean TES score:		4.30

6 Conclusions

- Laissez faire lab cultures pose an **unacknowledged safety risk**. For the sake of NT lab safety, *laissez faire* cultures must be transformed into “safety cultures.” Lab managers have a consensual ethical responsibility to actively promote such a culture.
- For a safety culture to exist in a NT lab, **much more is required than adherence to the rules** spelled out in conventional lab safety manuals. For example, about a quarter of respondents indicated beliefs that the primary response in their labs to rule-violating shortcutting would be “take no action.” Addressing safety risks posed by the behavior of others is as important as not causing them oneself.
- In light of pressures they acknowledge they often face in the NT lab, strong majorities of responding NT researchers believe that as a group they are **not** willing and able to effectively regulate their own lab practice and that it is **necessary** that clear ethical guidelines for the conduct of NT practice be developed and promulgated.
- The fact that researchers in NNIN labs come increasingly from quite different cultures around the world makes it naïve and dangerous to assume that they share the same culturally shaped notion of what responsible practice in the lab requires of them. Hence, **explicit and persistent socialization into the requirements of a robust safety culture in the NT lab is an ethical imperative**.
- Many responding NT researchers have serious reservations about the moral acceptability and safety of certain NT-related project goals that they deem likely to be pursued over the next 25 years, such as ones involving health-related HINDs, e.g., the project goal of enhancing human mental abilities.
- Most responding NT researchers have had no ethics education related to their work, do not feel well informed about ethical issues related to their work, and have a weak grasp of the ethics of precaution in NT lab settings. Nevertheless, a strong majority believe quite or very strongly that study of ethical issues related to science and technology should become an integral element of the education of future engineers and scientists. **This gap is a serious deficiency in the education of intending engineers and scientists and needs to be addressed sooner rather than later for the sake of the burgeoning, publicly supported, but still contested field of nanotechnology.**