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Is knowledge of science associated with higher skepticism of pseudoscientific claims?

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Appendix E - UNIVERSITY HONORS PROGRAM
SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Is knowledge of science associated with higher skepticism of pseudoscientific claims?

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

Signed: [signature], Faculty Mentor

Date: 4/29/03

General Assessment - please provide a short paragraph that highlights the most significant features of the project.

Comments (Optional):

Is knowledge of science associated with higher skepticism of pseudoscientific claims?

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Introduction

We live in a world that is increasingly being shaped by and bathed in science. The great majority of scientific progress has occurred in the past century, and most of it has been concentrated in the past 25 years. Human knowledge now spans from the astronomical scale to the quantum one. Yet, several authors have noted that modern societies are also characterized by a high degree of belief in a variety of pseudoscientific claims that have been thoroughly debunked or otherwise discarded by scientists (Anonymous 2001; Ede 2000).

The argument has been put forth that belief in pseudoscientific claims is the result of insufficient science education (references in Goode 2002; Walker et al. 2002). However, several polls have shown that at least for some areas of pseudoscience, education does not seem to correlate with skepticism (Goode 2002). For example, in the United States, the education category with the highest belief in extraterrestrial visits aboard UFOs is that of people with a college education (51%), although post-graduate education did lead to more skepticism (but still with 39% believers). Indeed, a study by Walker et al. (2002) conducted at three undergraduate universities in the U.S. has shown no correlation at all between knowledge of science and belief in an array of pseudoscientific claims.

A partial explanation for this state of affairs may be that science factual knowledge has little bearing on people's understanding of the evidence in favor or against pseudoscientific claims (Walker et al. 2002). It is well known that science education, especially (but not exclusively), at the pre-college level is the teaching of facts at the detriment of explicit treatment of methodological and conceptual issues surrounding the practice of science (Walker et al. 2002). It is not clear why educators would expect that massive factual knowledge of science should translate into conceptual understanding of the nature of science and into improved critical thinking skills, allegedly the true targets of science education.

This study addresses the issue of the relationships among science factual knowledge, conceptual understanding of science, and belief in pseudoscience with a 30-question survey consisting of three types of questions given to students enrolled in a science major, compared to the responses obtained by groups of non-science majors. The first class of questions was made of ten five-choice multiple choice questions intended to assess the students' general knowledge of science (e.g., about the periodic table or the nature of photons). The second set was constituted of ten true/false question that tests a respondent's understanding of important scientific concepts, such as the difference between theories and laws. The third class of questions quantified the respondents' degree of belief (on a scale of one to five, with five as highest belief) in paranormal phenomena, such as telepathy, astrology, or the existence of the Loch Ness monster.

By surveying science and non-science majors, we wished to test the following hypotheses of association among our measures of scientific knowledge, understanding, and paranormal belief:

> Science majors have more factual knowledge of science than non-science majors (since that is what they are primarily taught).
>
> Science majors have more understanding of conceptual issues in science (possibly because they are able to somehow derive it from factual knowledge to which they more mostly exposed).

Science majors express lower degrees of pseudoscientific belief than non-science majors (presumably because their knowledge of science makes them more skeptical of such claims).

There are no differences between genders for belief in pseudoscience, knowledge of science facts, or understanding of conceptual issues in science (even though recent surveys have found a higher degree of pseudoscientific belief in woman than men, though the trend is reversed for specific pseudoscientific claims, such as UFOs and unusual life forms, such as the Loch Ness monster: Anonymous 2001).

We also tested the following expectations concerning the pair wise relationships between the different types of questions we administered:

There is either a positive or no correlation between knowledge of science facts and understanding of science concepts (because factual knowledge somehow translates into conceptual understanding, or because the two are in fact uncorrelated; the only option that is not expected under any educational theory is that of a negative correlation between the two).

There is either a negative or no correlation between knowledge of science facts and degree of pseudoscientific belief (because factual knowledge of science does in fact indirectly foster critical thinking, or the two {science knowledge and critical thinking skills} are unrelated to each other; one would not expect the third outcome, that of a positive relationship between conceptual understanding of science and pseudoscientific belief).

There is either a negative or no relationship between understanding of science concepts and pseudoscientific belief (because conceptual understanding of science increases critical thinking, which leads to reduced belief in pseudoscience; alternatively, conceptual understanding of science does not translate into critical thinking skills, and hence has no positive relationship between science concepts and pseudoscience beliefs, is not expected under any scenario).

Materials and Methods

We assembled our 30-question survey (Appendix A) by examining two published surveys. The first one (Walker, et al. 2002) compared knowledge of scientific facts to pseudoscientific beliefs. Nine of the ten science fact multiple-choice questions used by those authors were kept, and we wrote one question of our own to replace the one removed. The one question was removed because it required specific knowledge of genetics, immunology, and reproduction, which we felt went beyond what could reasonably be expected at the level of introductory classes. The question we added tests a student's knowledge of the properties of a photon. For the pseudoscientific questions, we picked ten, out of the original 14, to place in the survey. We reduced the number of questions to eliminate overlapping topics (e.g. in the original questionnaire there were two questions about ghosts) and to focus on pseudoscientific beliefs that appear to be common. We also reduced the range of the belief scale from the original 1-7 to 1-5, with five indicating the highest level of belief.

For the scientific concepts portion of our survey, we selected ten true/false questions from Richard Carrier's Test of Scientific Literacy (http://www.infidels.org/library/modern/richard_carrier/SciLit.html 2001). Again, as in the previous case, we eliminated questions due to overlapping topics. We also eliminated questions that seemed highly technical or could be more easily misinterpreted by the students.

We randomized the order in which the 30 questions were presented in our survey, so that students would be less likely to try to second-guess the answers compared to a scenario in which it was more obvious that a series of pseudoscientific questions were presented after a series of fact- or concept-based questions.

We presented our survey to four classes, two second-year biology and two second-year philosophy classes. Our original experimental design assumed that philosophy majors would attend the philosophy classes, but due to class scheduling conflicts at the time of the survey, the only philosophy classes we had access to were in fact ethics classes attended by business majors. Overall, there were 170 respondents.

Students were asked during class to volunteer to take the survey. The survey administrator had no relationship with the class. Instructors were asked not to offer extra credit to students taking the survey. Students who responded to the survey were asked to provide only four pieces of personal information about themselves: age, gender, school year, and major. After instructions were given to the class, the administrator left the room for 15 minutes to ensure students did not feel pressured to take the survey. Students placed the surveys in a box left at the front of the room for the administrator to pick up after 15 minutes.

After we collected responses from all classes, we entered the results into a spreadsheet that was then imported into the statistical software Jump (SAS for Macintosh, v.5.01). We first calculated an average coefficient of scientific fact literacy, one of scientific concepts literacy, and one of pseudoscientific belief, simply by averaging the responses of each student to all questions within each of the three sets. We then ran an analysis of variance on each of the three summary indices with major, gender, and the major-by-gender interaction as factors. This would provide us with an overview of the association between major and gender with science literacy (both factual and conceptual) and pseudoscientific belief. Similar results were also obtained by running one-way non-parametric Kruskall-Wallis analyses of variance.

In order to obtain a more in-depth view of the same relationships we also ran a series of contingency analyses relating major and gender to the responses to each question within each set. We noted both the overall statistical significance of major and gender effects for each question, and the percentage of correct responses (in the case of science fact or concept questions) or the degree of pseudoscientific belief relative to the total.

We then considered the possible relationships among the three sets of measures, which were the major goal of this study. In order to quantify them, we calculated both non-parametric correlation coefficients (Spearman's and Kendall's) as well as parametric Pearson correlation coefficients between the each pair of overall indices of science factual knowledge, science conceptual understanding, and pseudoscientific belief. Results were very similar regardless of the specific correlation coefficient used.

Finally, we wished to quantify and visualize the similarities in students' responses to all thirty questions, which we accomplished by calculating an index of pairwise similarity between responses and subjecting the resulting matrix to a clustering algorithm, which produced a dendrogram (tree-like structure). Results were very similar when we used different indices of similarity (Gower's general similarity coefficient, Jaccard's coefficient, and the simple matching coefficient) suitable for categorical data such as ours (Sneath and Sokal 1973, pp. 129-137). Tree topology was also stable to the use of different clustering algorithms, such as unweighted arithmetic average (UPGMA), weighted arithmetic average (WPGMA), unweighted centroid (UPGMC), weighted centroid (WPGMC), and Ward's method (Sneath and Sokal 1973, pp. 214-244). All calculations of similarity indices and cluster analyses were conducted using the "R package" by Casgrain and Legendre, version 4.0, available at http://www.fas.umontreal.ca/biol/casgrain/en/labo/permute. On the resulting dendrogram, questions that tended to elicit similar responses across all classes of students were grouped together.

Results

Parametric analyses of variance of the relationship between Major, Gender, and Major-by-Gender interaction and the overall students' scores in science facts, science methods, and pseudoscientific belief (Table 1), found only a significant association between majors and their overall science fact score. The graph to the right of the table illustrates that science majors scored (predictably) better than non-science majors did on factual questions regarding a broad range of scientific fields, although the difference between the two groups was certainly not overwhelming. Similar results were also obtained using a series of non-parametric one-way ANOVAs (Kruskall-Wallis) on Major and Gender (details not shown).

The general results reported in Table 1 are consistent with the question-by-question analyses detailed in Tables 2-4 and based on a series of contingency tests. For example, note that while there are scattered significant effects of gender on science factual knowledge (Table 2), major on conceptual understanding of science (Table 3), and of gender on pseudoscientific belief (Table 4), the majority of individual significant effects were found for major on science factual knowledge. Interestingly, questions concerning factual knowledge of the physics of energy, the nature of photons, the difference between organic and inorganic matter, the metric system, the litmus test, and the relationship between earth-sun distance and the seasons all received low scores, with less than 50% of even the science majors getting them correct (boldface in Table 2).

Perhaps even more discouraging was the fact that no science method question received even 50% of correct answers, regardless of major or gender. Indeed, the difference between theory and laws was understood by less than 5% of the respondents in any category!

Perhaps a little more encouraging was the fact that the modal degree of belief in pseudoscientific claims was never higher than 3 (out of 5), and it was often lower than that (most frequently 1, the most skeptical response) (Table 4). Nevertheless, a low degree of skepticism was found for claims concerning the healing power of magnets, the presence of aliens in Area 51, and the existence of telepathy or clairvoyance (boldface in Table 4). On the positive side, students seemed to be particularly skeptical of the good or bad luck brought by chain letters and broken mirrors.

In order to determine the degree of correlation between the pairwise overall scores of students in pseudoscience, science facts, and science concepts, we calculated series of Spearman rank correlation coefficients (Table 5). They indicated that there was a weak positive correlation between knowledge of science facts and understanding of science concepts. We also found a weak negative correlation between pseudoscientific beliefs and science facts but apparently no relationship between pseudoscience belief and understanding of scientific concepts and methods. None of these correlation coefficients exceeded 0.27, however, indicating a large amount of unexplained variation in each indicator. Similar results were obtained using either Kendall's rank or Pearson parametric correlation coefficients.

Finally, a cluster analysis on the responses to all questions was performed using several measures of similarity and methods of hierarchical clustering (see Materials and Methods). The results reported here (Figure 1) were obtained by subjecting a matrix of Gower's general similarity coefficients to unweighted arithmetic average (UPGMA) clustering (though similar results were obtained with the other methods). Three measures of cophenetic correlation (Sneath and Sokal 1973, pp. 278-280) between the output of the clustering algorithm and the original similarity matrix were satisfactory, indicating that the dendrogram reliably reproduced the degree of similarity among responses to the various questions (the cophenetic coefficients were as follows: Kendall = +0.77; Pearson = +0.82; Gower = 2.98; notice that the first two vary between 0 and 1, where higher values indicate better fit, while the third one varies between 0 and infinity, and low values indicate better fit). The results show two major clusters, with several distinct sub-clusters. Most of the pseudoscience questions clustered together (bottom of diagram in Fig. 1), with the exception of those concerning luck brought by chain letters and broken mirrors (the same two for which students showed a high degree of skepticism), which clustered with a large number of mostly science fact questions (top portion of Fig. 1). The second major cluster was made of several sub-clusters, mostly with a mixture of science factual and conceptual questions, some of which are perhaps suggestive of interesting associations. For example, one tight cluster grouped together answers related to the ideas that scientific conclusions are tentative, that science is based on assumptions and postulates, and that theoretical entities are often featured in scientific conclusions. Other clusters, however, do not seem to hint at any simple relationship within or between the science facts and methods questions.

Discussion

Belief in all sorts of paranormal claims is very high in the United States, with recent surveys (Anonymous 2001) indicating, for example, that 36% of Americans think astrology is "very" or "sort of" scientific, 17% report having contacted a fortune teller, and a whopping 1/3 to half of Americans believing in UFOs. The causes of such widespread belief in irrational or unsubstantiated claims are difficult to pinpoint, as are potential trends (increasing or decreasing), due to the complexity of cultural forces involved and the lack of standardization across surveys.

Walker et al. (2002) have put forth the suggestion that science education is no guarantee of skepticism, and our general results seem to support the conclusions based on their own study. Walker et al. found no significant correlation between scores on a test of science literacy and degree of belief in an array of pseudoscientific claims when they surveyed three samples of undergraduate students at small universities in the United States.

Interestingly, work by Vitulli et al. (1999) found that belief in the paranormal is stronger in young males attending college as well as in elderly women, although they did find a possible positive effect of education: elderly people attending continuing education courses scores significantly lower in their belief in the paranormal (though, of course, this may have been due to a self-selecting effect).

The scope of our study was such that we could test some specific hypotheses concerning the expected association between indicators of science knowledge (both factual and conceptual) and of pseudoscientific belief. Of course, we were in no position to directly address the causal links between education and belief, although below we suggest some follow-up studies that might get closer to that goal. First, we hypothesized that science majors should display more knowledge of science facts than non-science majors, a minimalistic prediction if in fact science education has to have any effect whatsoever. Indeed, our results did confirm this expectation, although the difference between the scores of the two groups was not nearly as impressive as one might have hoped.

We also made the somewhat more risky prediction that science majors would display more conceptual understanding of science, allegedly the true goal of science education, than their non-science counterparts would. No such difference was found, which leads to at least questioning one of the most cherished assumptions of science educators: if we wish our students to understand how science works, confronting them with a lot of factual knowledge does not seem to help. Moreover, the general degree of conceptual understanding of science on the part of our students was abysmally low, especially in crucial areas such as the distinction between laws of nature (i.e., observations of regular patterns with no exceptions) and well-substantiated scientific theories (i.e., human interpretations of how the world works, which withstood repeated empirical tests).

The third prediction was even bolder: we speculated that science majors would display lower degrees of pseudoscientific belief, at least in part as a result of their science training (though, of course, effects due to self-selection are also possible). Again, we were disappointed: while students in our samples did show generally low degrees of pseudoscientific belief (with the notable exceptions of the healing powers of magnets, the existence of aliens being held at the government facility known as "Area 51," and the existence of telepathy or clairvoyance), no difference was found between the majors.

We also investigated the possibility of existence of differences in our indicators between genders, given the repeated observation of such differences in previous surveys. For example, belief in all (though not all) paranormal phenomena was found to be higher in women than men by a survey conducted by the National Science Foundation (Anonymous 2001), and a survey by Irwin (1985) found that belief in the paranormal is stronger in women than men. Our overall results did not show any such difference when an average indicator of pseudoscientific belief was considered, nor were gender differences significant for overall science factual or conceptual knowledge. However, more detailed analyses did reveal a hint of some differences between genders. For example, female students knew slightly better than their male counterparts about the dominant source of energy on earth and about the nature of infectious disease, though it is difficult to speculate on the causes of this difference, and we are inclined to attribute them to statistical fluctuations. Significantly, we found no differences between genders even upon a more in-depth analysis in the area of conceptual understanding of science, while men were less likely to believe in the existence of the Loch Ness monster and more likely to think that animals can sense ghosts. Again, however, it is possible that the latter two findings were due to statistical fluctuations and carry no general meaning.

One of the major goals of our research was to investigate the possible relationships between our three indices of knowledge of science fact and pseudoscientific belief. Under the most optimistic scenario, we had predicted a positive association between knowledge of science facts and understanding of science concepts (if the standard educational assumption holds), and a negative association between either measure of science literacy and pseudoscientific belief (under the assumption that more knowledge of science makes for better critical thinking, and therefore more skepticism about pseudoscience).

The first prediction turned out to be correct, although the strength of the association between knowledge of science facts and understanding of concepts was very weak. This is consistent with the idea that there is some detectable seepage from learning many facts about science to a higher-level understanding of how science works. However, the weakness of the relationship strongly suggests that there must be better ways of achieving this, consistently with recent literature on science teaching and critical thinking (Wandersee 1990; Sundberg et al. 1994; Belzer et al. 2003).

On the other hand, neither knowledge of science facts nor understanding of scientific concepts seemed to be associated with the degree of belief in pseudoscience (though both correlation coefficients were in the right direction, that is, negative). This, of course, is subject to several interpretations, and does not necessarily mean that a better understanding of science does not foster critical thinking. However, it does mean that whatever association there may be between knowledge of science and skepticism about pseudoscience, it is not very strong or particularly evident. Indeed, even at the much more sophisticated level of graduate studies, Lehman et al. (1988) found that training in the hard sciences (chemistry) did not result in a high level of transferability of critical thinking skills to everyday problems. On the other hand, graduate students in the social sciences (psychology), who are continuously exposed to complex problems characterized by probabilistic answers, seem to be much better equipped to apply their critical thinking skills to other domains than academic research. This is particularly interesting in this context because it argues that another assumption commonly made by science educators, that science training makes for better critical thinkers, may not be true even at the level of graduate studies, let alone undergraduate.

Several caveats and possible future directions in regards to this study need to be briefly discussed. One obvious limitation of our research is that it did not include a longitudinal component to help discriminate between the actual effect of teaching science and the possibility of self-selection of more critically thinking students into scientific disciplines. However, since we did not find significant differences in this respect between science and non-science majors, our results can hardly be attribute to self-selection processes. Nevertheless, it would be interesting to compare, for example, freshman and seniors in science vs. non-science majors, with the idea that any difference between groups that increases with time would be likely due to training rather than self-selection. It is of course possible that both effects contribute, which would translate into a significant year-by-major interaction in an analysis of variance.

Secondly, it would be interesting to examine the possible differences between actual philosophy students and science majors, as opposed to business students taking ethics classes in philosophy, as it happened in our case. The reason for this is that philosophers are among the few majors who actually get formal training in critical thinking, both through courses explicitly designed for that purpose, as well as through rigorous training in logical and conceptual analyses of any course material to which they are exposed.

Thirdly, it would be interesting to expand the study to include graduate students, comparing them between disciplines (a la Lehman et al 1988), as well as with beginning and advanced undergraduates. One would expect that graduate students might be more skeptical than undergraduates of pseudoscientific claims regardless of their discipline because of more maturity and education. However, we also predict differences in critical thinking abilities between philosophy and science graduate students (to the advantage of the former) and among different kinds of graduate students (to the advantage of people working on complex problems characterized by probabilistic approaches, such as psychology and organismal biology).

Overall, much more needs to be understood about the relationship among factual knowledge of science, its conceptual understanding, critical thinking, and belief in pseudoscience (which, incidentally, does not itself represent a homogeneous category, with surveys showing distinctions between different kinds of pseudoscientific belief: Anonymous 2001; Goode 2002). Certainly, we cannot simply assume that all we need to do in order to improve critical thinking and reasonable skepticism is to teach more science facts.

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Table 1. Analyses of variance of the relationship between Major, Gender and Major-by-Gender interaction and the overall students' scores in science facts, science methods and pseudoscience belief. R^2 indicates the amount of variance explained by the model, numbers in parenthesis on the top row indicate degrees of freedom of each effect. In the main body of the table, means squares values are reported, together with their associated level of statistical significance (in parentheses). The graph illustrates the mean differences between groups in the only case in which significant differences were detected. Notice that similar results were obtained by running non-parametric one-way ANOVAs (Kruskal-Wallis) on Major and Gender.

Variable	R^2	Major (1)	Gender (1)	Major x Gender (1)	error (142)
Overall science fact score	24.7%	**0.8419 (0.0001)**	0.0019 (0.7570)	0.0326 (0.2026)	0.0199
Overall science methods score	1.4%	0.0315 (0.3090)	0.0146 (0.4878)	0.0001 (0.9474)	0.0302
Overall pseudoscience belief	1.0%	0.1840 (0.4713)	0.4450 (0.2631)	0.0011 (0.9552)	0.3526

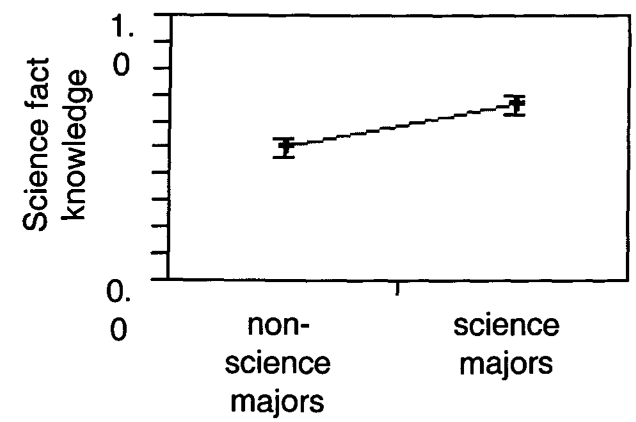

Table 2. Contingency analyses of the responses to questions on **science facts**, by Major (non-science vs. science) and Gender. Questions highlighted in boldface were characterized by a particularly poor response (i.e., no category reached 50% of correct answers). Percentages refer to *total* correct answers (to provide determine how many people responded correctly or incorrectly overall), which means that they do not add up to 100% within factors. Boldfaced p-values highlight particularly striking differences between Majors or Genders (i.e., p<0.01).

	Major				**Gender**			
Question	*non-science*	*science*	*likelihood ratio*	*p-value*	*female*	*male*	*likelihood ratio*	*p-value*
Dominant source of energy on earth	34.8%	52.8%	11.919	**0.0006**	45.5%	41.3%	7.105	**0.0077**
Physics of energy	34.6%	49.4%	5.177	0.0229	41.9%	42.5%	0.475	0.4906
Nature of photons	14.8%	14.2%	0.961	0.3270	13.7%	14.9%	0.002	0.9611
Nature of infectious disease	27.2%	51.9%	26.154	**0.0001**	42.9%	35.7%	8.363	**0.0038**
Organic vs. inorganic	22.1%	43.6%	15.775	**0.0001**	34.9%	31.4%	2.310	0.1286
Periodic table	35.2%	54.3%	21.057	**0.0001**	43.5%	45.8%	0.011	0.9149
Metric system	29.0%	38.9%	0.753	0.3856	32.1%	36.9%	0.765	0.3818
Litmus test	20.6%	46.3%	24.411	**0.0001**	34.3%	31.9%	0.765	0.3816
Genetic disorders	40.5%	54.0%	4.319	0.0377	47.0%	47.0%	1.550	0.2131
Earth-Sun distance and seasons	8.6%	9.3%	0.147	0.7014	6.6%	12.5%	3.348	0.0673

Table 3. Contingency analyses of the responses to questions on **science concepts**, by Major (non-science vs. science) and Gender. Questions highlighted in boldface were characterized by a particularly poor response (i.e., no category reached 50% of correct answers). Percentages refer to *total* correct answers (to provide determine how many people responded correctly or incorrectly overall), which means that they do not add up to 100% within factors. Boldfaced p-values highlight particularly striking differences between Majors or Genders (i.e., p<0.01). Notice that *all* questions received very low overall percentages of correct answers, and that there were few significant differences between levels of the factors.

	Major				**Gender**			
Question	*non-science*	*science*	*likelihood ratio*	*p-value*	*female*	*male*	*likelihood ratio*	*p-value*
Science produces tentative conclusions	27.6%	39.9%	2.050	0.1522	32.5%	33.1%	0.137	0.7111
Is there only one scientific method?	26.1%	36.0%	0.789	0.3744	34.7%	28.1%	4.289	0.0384
Theories are explanations, not facts	36.4%	44.4%	0.001	0.9901	36.9%	43.5%	2.298	0.1295
Is science just about facts or about interpretations?	35.0%	47.9%	2.077	0.1495	42.0%	40.8%	1.587	0.2077
Does science require to conduct experiments?	19.8%	27.2%	0.506	0.4769	21.4%	25.6%	0.627	0.4285
Can experiments prove theories?	11.8%	26.1%	8.131	**0.0044**	19.8%	18.0%	0.435	0.5094
Science includes beliefs, assumptions & non-observables	25.9%	27.8%	0.785	0.3755	26.2%	27.4%	0.035	0.8509
Are laws exceedingly well confirmed theories?	3.1%	5.0%	0.273	0.6013	4.8%	3.0%	1.055	0.3044
A theory is a hypothesis that has been amply confirmed	38.9%	49.4%	0.074	0.7852	43.5%	44.6%	0.132	0.7162
Science uses theoretical entities that have never been observed	30.3%	34.6%	0.311	0.5769	31.7%	33.5%	0.029	0.8655

Table 4. Contingency analyses of the responses to questions on **pseudoscientific beliefs**, by Major (non-science vs. science) and Gender. Questions highlighted in boldface were characterized by a particularly low skeptical response (i.e., not even 50% of students in any category expressed complete disbelief). Entries under the levels of each factor indicate the modal response (from 1 to 5, with 5 as the highest degree of belief), and the percentage of students (within each level of each factor) answering in that fashion (in parentheses). Boldfaced p-values highlight particularly strikingly (i.e., $p<0.01$) differences between Majors or Genders. Notice that there were few significant differences between levels of the factors.

	Major				**Gender**				
Question	*non-science*	*science*	*likelihood ratio*	*p-value*	*female*	*male*	*likelihood ratio*	*p-value*	*least skeptical*
Magnets can heal	3 (39.7%)	3 (42.2%)	3.587	0.4648	3 (42.7%)	3 (39.1%)	2.950	0.5661	
There are aliens in area 51	2-3 (30.1%)	3 (30.0%)	0.999	0.9100	3 (29.3%)	2 (29.9%)	0.636	0.9589	
Telepathy or clairvoyance are real	2 (38.4%)	2 (32.2%)	4.237	0.3748	2 (35.4%)	1 (40.2%)	6.862	0.1434	
Astrology predicts personality & future	1 (52.1%)	1 (48.9%)	2.311	0.6787	1 (40.2%)	1 (60.9%)	10.441	0.0336	
Bigfoot exists	1 (58.9%)	1 (50.0%)	9.385	0.0522	1 (56.1%)	1 (50.6%)	4.081	0.3952	
The Loch Ness monster exists	1 (52.1%)	1 (41.1%)	7.339	0.1190	1 (47.6%)	1 (44.8%)	18.508	**0.0010**	males
Sending chain letters brings good luck	1 (80.8%)	1 (87.8%)	8.264	0.0409	1 (81.7%)	1 (88.5%)	3.785	0.2856	
Animals can sense ghosts	1 (48%)	1 (40.%)	1.256	0.8688	1 (31.7%)	1 (53.5%)	15.191	**0.0043**	females
Voodoo kils	1 (58.3%)	1 (55.6%)	0.972	0.9141	1 (51.2%)	1 (61.6%)	3.796	0.4343	
Broken mirrors bring bad luck	1 (72.6%)	1 (82.2%)	3.641	0.3029	1 (72.0%)	1 (85.1%)	7.977	0.0465	

Table 5. Pairwise Spearman's rank correlation coefficients relating overall scores of students in pseudoscience, science facts and science concepts categories. Significance levels of the statistical tests are in parentheses. Similar results were obtained using either Kendall's rank or Pearson parametric correlation coefficients.

	Pseudoscience	Science facts
Science facts	-0.18 (0.0228)	
Science concepts	-0.06 (0.4383)	+0.27 (0.0007)

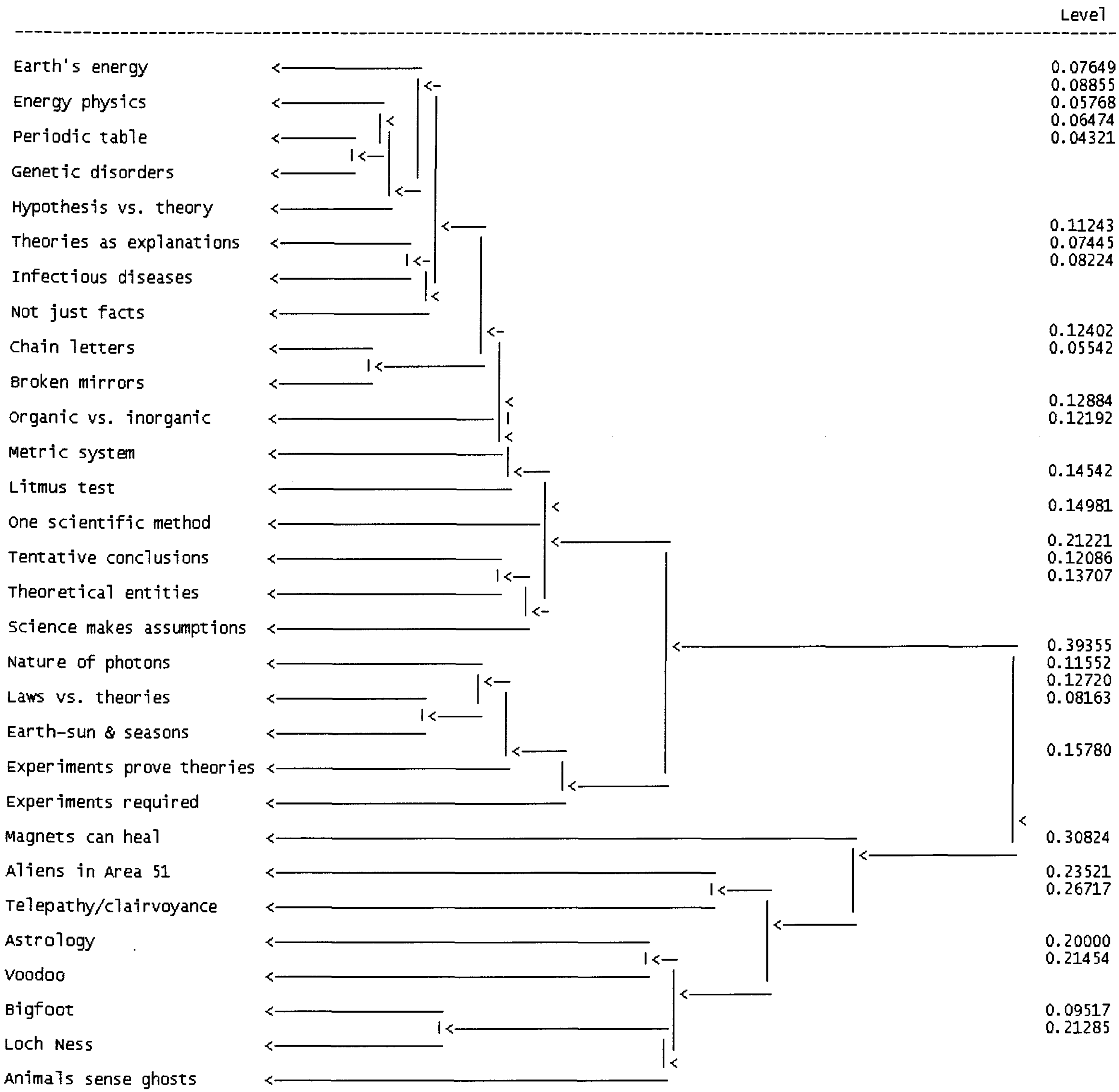

Figure 1. Cluster analysis of the similarities in students' responses to the thirty questions on science facts, science concepts and pseudoscience. Numbers on the right quantify similarities between objects within each cluster. The dendrogram is based on unweighted arithmetic average (UPGMA) of a matrix of similarities calculated using Gower's general similarity coefficient. Measures of cophenetic relationships between the derived and original matrix (Kendall's tau = 0.77, Pearson's r = 0.82, and Gower's distance = 2.98), indicated a good fit between the dendrogram and the similarity matrix. The same topology was obtained by subjecting the same coefficients to other clustering methods, and the major features of the topology were retained when using different coefficients of similarity, such as Jaccard's and the simple matching coefficient. These other methods, however, yielded a lower fit between tree topology and similarity matrix when measured by the above-mentioned cophenetic coefficients, and did not resolve the differences among the responses to the questions on pseudoscientific beliefs.

Appendix A
Survey Responses

Major:

____

Year:

____

Age:

____

Gender:

____

Survey

Please circle what, in your opinion, is the best answer.

1. Which of the following is the dominant source of all or nearly all of the Earth's energy?
   (A) Plants, (B) Animals, (C) Coal, (D) Oil, (E) The Sun

2. Which of the following is true?
   (A) Energy may be converted from one form to another
   (B) Energy may not be converted from one form to another
   (C) The energy that a moving object possesses because of its motion is correctly known as potential energy
   (D) Objects which possess energy because of their position are said to have kinetic energy
   (E) Most scientists readily agree that energy from nuclear fission will be the chief source of energy by the year 2005

3. The body can be healed by placing magnets onto the skin near injured areas.
   1=I do not believe in this at all
   2=I doubt that this is real
   3=I am unsure if this is real or not
   4=I believe this is real
   5=I strongly believe this is real

4. Science only produces tentative conclusions that can change. T / F

5. Science has one uniform way of conducting research called "the scientific method." T / F

6. A photon is?
   (A) A particle
   (B) A wave
   (C) A unit of energy
   (D) A particle and a wave, depending on the circumstances
   (E) A theoretical entity used to explain light

7. The government is hiding evidence of alien visitors at places such as Area 51.
   1=I do not believe in this at all
   2=I doubt that this is real
   3=I am unsure if this is real or not
   4=I believe this is real
   5=I strongly believe this is real

8. Scientific theories are explanations and not facts. T / F

9. A person can use their mind to see the future or read other people's thoughts.
   1=I do not believe in this at all
   2=I doubt that this is real
   3=I am unsure if this is real or not
   4=I believe this is real
   5=I strongly believe this is real

10. A person's astrological sign can predict a person's personality and their future.
- 1=I do not believe in this at all
- 2=I doubt that this is real
- 3=I am unsure if this is real or not
- 4=I believe this is real
- 5=I strongly believe this is real

11. Heavy infections of *Trichinella* in people may cause a disease called trichinosis; such a situation may best be described as which of the following?
- (A) Parasitism
- (B) Mutualism
- (C) Commercialism
- (D) Benevolent
- (E) Benign

12. Which of the following is the main difference between an organic and an inorganic compound?
- (A) The former is a living compound, while the latter is a nonliving compound
- (B) There are many more of the latter than of the former
- (C) The latter can be synthesized only by living organisms
- (D) The latter can be synthesized only by nonliving organisms
- (E) The former are those that contain carbon.

13. On the periodic table the symbol Pb represents which of the following?
(A) Iron, (B) Phosphorus, (C) Lead, (D) Plutonium, (E) Potassium.

14. An ape-like mammal, sometimes called Bigfoot, roams the forests of America.
- 1=I do not believe in this at all
- 2=I doubt that this is real
- 3=I am unsure if this is real or not
- 4=I believe this is real
- 5=I strongly believe this is real

15. Science is just about the facts, not human interpretations of them. T / F

16. To be scientific one must conduct experiments. T / F

17. A dinosaur, sometimes called the Loch Ness Monster, lives in a Scottish Lake.
- 1=I do not believe in this at all
- 2=I doubt that this is real
- 3=I am unsure if this is real or not
- 4=I believe this is real
- 5=I strongly believe this is real

18. Sending chain letters can bring you good luck.
- 1=I do not believe in this at all
- 2=I doubt that this is real
- 3=I am unsure if this is real or not
- 4=I believe this is real
- 5=I strongly believe this is real

19. An experiment can prove a theory true. T / F

20. Which of the metric terms is closest to the measurement of a new piece of chalk?
(A) Meter, (B) Liter, (C) Kilogram, (D) Decimeter, (E) Kilometer.

21. A litmus test conducted on HCl would have which of the following results?
    (A) There is no effect on the color of the litmus paper
    (B) The litmus paper disintegrates
    (C) The litmus paper turns blue
    (D) The litmus paper turns red
    (E) The carbonation causes oxygen

22. Science is partly based on beliefs, assumptions, and the nonobservable. T / F

23. Animals, such as cats and dogs, are sensitive to the presence of ghosts.
    1=I do not believe in this at all
    2=I doubt that this is real
    3=I am unsure if this is real or not
    4=I believe this is real
    5=I strongly believe this is real

24. Which of the following is a genetic disorder?
    (A) Down's Syndrome, (B) Syphilis, (C) Malaria, (D) Leukemia, (E) Emphysema.

25. A scientific law is a theory that has been extensively and thoroughly confirmed. T / F

26. An accepted scientific theory is an hypothesis that has been confirmed by considerable evidence and has endured all attempts to disprove it. T / F

27. Voodoo curses are real and have been known to kill people.
    1=I do not believe in this at all
    2=I doubt that this is real
    3=I am unsure if this is real or not
    4=I believe this is real
    5=I strongly believe this is real

28. Scientists accept the existence of theoretical entities that have never been directly observed. T / F

29. A broken mirror can bring you bad luck for many years.
    1=I do not believe in this at all
    2=I doubt that this is real
    3=I am unsure if this is real or not
    4=I believe this is real
    5=I strongly believe this is real

30. When is the Earth closest to the Sun? (Assume seasons in the Northern hemisphere)
    (A) During the summer, (B) During the fall, (C) During the winter
    (D) During the spring, (E) During the spring and summer.

Answers

1. E
2. A
4. T
5. F
6. E
8. T
11. A
12. E
13. C
15. F
16. F
19. F
20. D
21. D
22. T
24. A
25. F
26. T
28. T
30. C