SCIENCE LEARNING IN EVERYDAY LIFE

Lynn D. Dierking and John H. Falk, Section Coeditors

# Using Questions Sent to an Ask-A-Scientist Site to Identify Children's Interests in Science

AYELET BARAM-TSABARI
*Department of Science Teaching, Weizmann Institute of Science, Rehovot 76100, Israel*

RICKY J. SETHI
*Department of Computer Science and Engineering, University of California, Riverside, CA 91801, USA*

LYNN BRY
*Department of Pathology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA 02115, USA*

ANAT YARDEN
*Department of Science Teaching, Weizmann Institute of Science, Rehovot 76100, Israel*

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**ABSTRACT:** Interest is a powerful motivator; nonetheless, science educators often lack the necessary information to make use of the power of student-specific interests in the reform process of science curricula. This study suggests a novel methodology, which might be helpful in identifying such interests—using children's self-generated questions as an indication of their scientific interests. In this research, children's interests were measured by analyzing 1555 science-related questions submitted to an international Ask-A-Scientist Internet site. The analysis indicated that the popularity of certain topics varies with age and gender. Significant differences were found between children's spontaneous (intrinsically motivated) and school-related (extrinsically motivated) interests. Surprisingly, girls contributed most of the questions to the sample; however, the number of American girls

*Correspondence to:* Anat Yarden; e-mail: anat.yarden@weizmann.ac.il

dropped upon entering senior high school. We also found significant differences between girls' and boys' interests, with girls generally preferring biological topics. The two genders kept to their stereotypic fields of interest, in both their school-related and spontaneous questions. Children's science interests, as inferred from questions to Web sites, could ultimately inform classroom science teaching. This methodology extends the context in which children's interests can be investigated. *Sci Ed*, 1–24, 2006

## THEORETICAL FRAMEWORK

The Glenn report *Before It's Too Late* (The National Commission on Mathematics and Science Teaching for the 21st Century, 2000) states that "we are failing to capture the interest of youth for scientific and mathematical ideas." Indeed, many students find standard science curricula largely out of touch with their personal interests, a factor which contributes to the low number of students pursuing advanced science and mathematics courses in high school, and going on to choose scientific careers (Millar & Osborne, 1998). Adolescents' decisions about the contents and directions of their educational training have been found to be influenced to a high degree by the topic-related interests they developed in the preceding years (Krapp, 2000).

Organizations, including the National Research Council (1996) and the American Association for the Advancement of Science (1993), have proposed that science curricula taught at a secondary-school level should provide a common basis of knowledge while addressing the particular needs and interests of students. However, educators lack the necessary information and tools to guide modifications that could make use of the power of student-specific interests in improving those students' individualized learning and competency in scientific subjects.

The issue of students' interests may also be viewed in the context of the pupil's voice in the education movement (Burke & Grosvenor, 2003; Economic and Social Research Council, 2004; Mirta, 2004; Whitehead & Clough, 2004). Until recently, the pupil's voice had been marginalized or neglected by educational researchers. The student was regarded as an object of study but not as someone who could make an informed judgment on what should be taught in school science courses (Jenkins & Nelson, 2005). Lloyd-Smith and Tarr (2000) have called for the educational system, as frontline providers for children, to model, for other professionals, a real process of acknowledging and valuing young people's views and opinions. Similarly, Rudduck and Flutter (2000) regard it as strange that, in a climate that privileges the consumer, pupils in school have not been considered consumers worth consulting.

Interest is a powerful motivator (Deci, 1992), which differs from most other motivational concepts by its content specificity (Krapp, 2002). Interest refers to a differential likelihood of investing energy in one set of stimuli rather than another (Csikszentmihalyi & Hermanson, 1995). Research indicates positive relationships between individual interest and a wide range of indicators of learning (Pintrich & Schunk, 2002; Schiefele, 1998). However, the potential benefits of interest have been largely ignored in school reform: students rarely learn out of interest, and they usually lose interest during learning (Prenzel, 1998), with the consequence that bored and unengaged students are also less likely to learn (Blumenfeld et al., 1991).

A number of studies have explored students' scientific interests by inviting them to respond to questionnaires (Dawson, 2000; Qualter, 1993; Sjøberg, 2000; Sjøberg & Schreiner, 2002; Stark & Gray, 1999), participate in focus groups (Osborne & Collins, 2000, 2001), or respond to a student-led review of the science curriculum (Murray & Reiss, 2005). These techniques have identified age-, gender-, and subject-specific issues impacting students' general interests in specific subjects, including a significant decline in interest in physics, chemistry, and mathematics that occurs as the students' progress in grade level. This decline is particularly evident as students enter high school, and is especially pronounced for girls (Krapp, 2002).

The gender-related aspects of the interest theory for science education are that boys in general have greater interest in science than girls (Gardner, 1975 1998), and while physics proves significantly less interesting to girls than to boys, biology is of greater interest to girls (Dawson, 2000; Friedler & Tamir, 1990; Jones, Howe, & Rua, 2000; Sjøberg, 2000; Stark & Gray, 1999; Zohar, 2003). Within the field of biology, high school girls were shown to display greater interest in human biology than boys, in both Israel (Tamir & Gardner, 1989) and England (Taber, 1991). The relevance of science education (ROSE) studies conducted in England and Denmark found that girls' interest was focused on health, medicine, and the body, whereas boys wished to learn more about the dramatic aspects of physics and chemistry, and how technology works (Busch, 2005; Jenkins & Nelson, 2005). Moreover, subject-matter related interests have a greater influence on boys' grades than girls' (Schiefele, Krapp, & Winteler, 1992).

The questionnaire-based methods usually used to explore students' scientific interests have traditionally relied on adult-centric views of what subjects should be meaningful for students. To overcome this inherent bias, we developed a naturalistic approach to defining students' specific concerns by using children's self-generated questions as an indication of their scientific interests.

Posing questions is an important part of scientific inquiry (National Research Council, 1996). Self-generated questions can help reveal the asker's reasoning, alternative views, and interests (Biddulph, Symington, & Osborne, 1986). Studying students' questions can give teachers an awareness of what students are interested in and what they want to know about a given topic (Chin & Chia, 2004).

The best known and most often used way of classifying students' questions according to their cognitive level is the hierarchical Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), which suggests classifying questions into low-order (knowledge, comprehension, application) and high-order (analysis, synthesis, evaluation) questions. A simpler evaluation involves distinguishing among input questions—those which require recalling knowledge, processing questions—which require linking pieces of information, and output questions—which require hypothesizing, generalizing, and criticizing (Shepardson & Pizzini, 1991). Graesser, Person, and Huber (1992) proposed analyzing a question according to the hierarchical content of the information requested, with deep-reasoning questions being highly correlated with the deeper levels of cognition in Bloom's taxonomy. Marbach-Ad and Sokolove (2000) classified students' questions into eight categories, the highest one being a research hypothesis. Another taxonomy of questions distinguishes between "confirmation questions," and the higher quality "transformation questions," which signal the restructuring or reorganization of students' understanding (Pedrosa de Jesus, Teixeira-Dias, & Watts, 2003).

Students rarely ask questions in the classroom, and when they do, only a very small subset of their questions evidence genuine intellectual curiosity (Dillon, 1988; Graesser & Person, 1994; Marbach-Ad & Sokolove, 2000; Pedrosa de Jesus et al., 2003; Rop, 2003; White & Gunstone, 1992). The overall paucity of student questioning is attributed to the classroom atmosphere, where revealing a misunderstanding renders the student vulnerable, open to embarrassment, censure or ridicule (Pedrosa de Jesus et al., 2003). Students described their teachers' response to their questions as "put-offish" or even annoyed, and their classmates' reactions as intolerant (Rop, 2003).

Learners usually ask questions where they feel secure (Watts, Gould, & Alsop, 1997). We therefore looked for self-generated questions in free-choice science-learning environments.

Examining free-choice science-learning environments can provide knowledge about the natural setting in which people learn in a self-directed, self-motivated, voluntary way, guided by individual needs and interests (Falk & Dierking, 2002), and has much to offer to formal education (Walter & Westbrook, 2001). An example of such a free-choice setting is the Web, which can be seen as a site for student inquiry in science, which allows students to pursue questions of personal interest (Wallace, Kupperman, Krajcik, & Soloway, 2000).

Research on children's use of the World Wide Web for learning has generally been conducted in school settings. In the fall of 2003, nearly all of the public schools in the United States had access to the Internet (National Center for Education Statistics, 2005). Students reported regularly accessing science sites to get help with school assignments (Weigold & Treise, 2004). Nevertheless, although they exhibit positive attitudes and self-confidence (Fidel et al., 1999; Lumpe & Bulter, 2002; Watson, 2004), children have difficulty formulating and modifying search queries (Bilal, 2004; Hirsh, 1999; MaKinster, Beghetto, & Plucker, 2002; Wallace et al., 2000). Furthermore, children do not tend to question the accuracy of the information they find on the Web (Hirsh, 1999; Schacter, Chung, & Dorr, 1998; Wallace et al., 2000).

Students using the Web are often overwhelmed by the amount of information available (MaKinster et al., 2002). An effective search is also an exercise in inquiry and critical thinking (Brem & Boyes, 2000). Most students fail to construct an accurate and broad understanding following an online inquiry (Hoffman & Krajcik, 1999). However, a deficiency in students' skills is not always to blame: Keating, MaKinster, Mills, and Nowak (1999) found that only 30% of the search results they received actually contained at least a short operational definition or graphic display of the science concept they were searching for, and many of the sites contained misconceptions.

Sometimes, when children are trying to find complex answers on the Web, they need people who have the answers, rather than a list of directories or sites. These human-mediated question-and-answer services are sometimes referred to as "Ask-A" services, such as "Ask a Scientist" (Lankes, 1999) or "Expert Services" (Janes, Hill, & Rolfe, 2001). These digital reference services allow one to send questions that interrogate a collective cranium of experts versed in a variety of disciplines (Parslow & Wood, 1998). They are oriented to matching the asker with people having the expertise to answer his/her questions, not just to matching an information need to a textual source with the information (White, 1999). The mode of communication is asynchronous electronic communication. Usually, such sites maintain searchable public archives in which previously answered questions are returned as search results, thus making this archive a resource for their users (Pomerantz, Nicholson, Belanger, & Lankes, 2004).

In this research, we used children's questions asked under free-choice conditions to identify their scientific interests. Using a similar methodology, we were previously able to characterize Israeli students' interests in science and technology (Baram-Tsabari & Yarden, 2005). The ability to identify students' interests in science may play an important role in improving existing curricula to meet their needs. This study aims to assist science educators, teachers, and curriculum developers in identifying such student interests using a novel methodology.

## METHODOLOGY

### Data Source

MadSci Network is an independent, award-winning, nonprofit organization operating from a server in Boston (http://www.madsci.org). Unlike most Ask-A-Scientist services (see further on), MadSci Network covers all branches of science, and does not focus on a specific subject area. It collects as much, and potentially more information than most Ask-A-Scientist services, and stores key demographic information as meta-data, making it easier to mine the information from the archives. The MadSci Network receives 90–150 questions daily, which are answered by nearly 800 scientists.

Many other English-language Ask-A-Scientist services are available on the Net, but none were found suitable for our research. The services run by Scientific American[1] and the Internet Public Library,[2] for instance, do not ask for the age of the questioner. The paid service Google Answer[3] does not have any information about the askers. The Argonne National Labs[4] Ask-A-Scientist service records geographical information only about Americans, while Ask Dr. Universe[5] is aimed mostly at elementary-school children. Many other services only answer questions on a specific topic. The service run by Howard Hughes Medical Institute,[6] for example, receives only biology questions, while Ask Dr. Math,[7] obviously, deals with math questions.

## The Sample

Questions submitted to the MadSci Network by 4th- through 12th-grade students from August to October 2004 were collected, resulting in a sample number of 1555. For each entry, information was recorded about the question, age group, first name, and country of origin of the asker. Questions automatically answered by the archives search engine were not included, since the system did not record them. Questions asked by populations other than 4th- through 12th-grade students were also excluded.

More than 94% of the contributors originated from English-speaking countries, most of them from the United States (71.7%), Australia and New Zealand (7.2%), Canada (6.1%), and the United Kingdom (4.6%). We assume that this bias reflects the number of people with Internet access and fluency in English, as well as the English-based nature of the MadSci Network, rather than a more pronounced interest in science. Half of the contributors were high school students, 39% were in junior high school, and the remaining 11% were 4th- to 6th-graders. The first name was used to determine the asker's gender, using an English name gender finder (Na-Demo-Ya, 2002). In this manner, we were able to identify 1167 of the contributors, who were divided into 56.4% female and 43.6% male. The age and gender split differed between countries, with the United States being characterized by more young and more female contributors relative to other countries.

## Classifying the Questions

The questions were classified with reference to several coding schemes.

***Field of Interest.*** The most straightforward classification was field of interest. In this coding scheme, questions were placed in one of the following categories: "biology," "physics," "chemistry," "earth sciences," "astrophysics," "technology," "nature of science inquiry (NOS)," and "mathematics." "Technology" questions were categorized by defining

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[1] http://www.sciam.com/page.cfm?section=expertform

[2] http://www.ipl.org/div/askus/

[3] http://www.answer.google.com/answers/

[4] http://www.newton.dep.anl.gov/archive.htm

[5] http://www.wsu.edu/DrUniverse/

[6] http://www.hhmi.org/askascientist/

[7] http://mathforum.org/dr.math/ask/submit.html

technology as the development, production, and maintenance of objects in a social context, as well as the objects themselves (Gardner, Penna, & Brass, 1996). NOS questions asked about how scientists develop and use scientific knowledge (Ryder, Leach, & Driver, 1999) without reference to a specific scientific context.

The categories were further divided into 58 subcategories (for the full list, see Appendix). Using this scheme, only 22 questions failed to fit any category, and were designated "undistinguished" (e.g., "What is astrology and how do horoscopes influence people's lives?"). For examples of the application of the categories and subcategories in this coding scheme, see Table 1.

Many of the questions in the field of biology were embedded in the context of human biology or the zoology of nonhumans, e.g., "Is our inability to synthesize vitamin C an inborn error of metabolism?" (10th–12th grade, female, UK), "Do dogs have a dominant paw that they prefer to use?" (7th–9th grade, female, US). These questions were classified as portraying a "human" and "zoology" interest, respectively.

***Spontaneous Versus School-Related Motivation for Raising the Question.*** Gross (2001) makes a distinction between questions that are self-generated (internally motivated by personal context) and those that are imposed (thought up by one person, such as a teacher, and then given to someone else, such as a student, to resolve). Intrinsic motivation refers to doing something because it is inherently interesting or enjoyable. Extrinsic motivation refers to doing something because it leads to a separable outcome (Ryan & Deci, 2000) as a means to an end (such as praise or avoiding punishment) (Vallerand et al., 1992). In school, intrinsic motivation becomes weaker with each advancing grade (Ryan & Deci, 2000). Most learning in school is extrinsically motivated, and the acquisition of knowledge is rarely enjoyed for its own sake (Csikszentmihalyi & Hermanson, 1995).

Although all of the questions in our sample were generated by students, not all of them were the outcome of an intrinsic motivation to know. Many of the questions were required for school assignments and were originally raised by teachers or textbooks. To differentiate between the two types of motivation for raising the question, we classified the questions as either "spontaneous," which can serve as an indication of intrinsic motivation to know, or "school related," which can serve as an indication of an extrinsic motivation for seeking an answer.

Questions were classified as school related only if it was explicitly stated in the question that the information is required for a school assignment, such as a science fair project, report, and homework. All other questions were classified as spontaneous. For examples of the application of the categories in this coding scheme, see Table 1.

***Cognitive Level of the Question.*** Two classification methods to hierarchically describe the cognitive level of the questions were used here: order of information requested and type of information requested (see further on).

Many schemes were suggested for classifying the cognitive level of students' questions, but they did not fit the nontraditional sample used in this research, because they are only suitable for questions asked in the context of a textbook (Shepardson & Pizzini, 1991), a discourse (Graesser et al., 1992), or a classroom setting where questions are categorized with respect to the task at hand (Marbach-Ad & Sokolove, 2000; Pedrosa de Jesus et al., 2003). This was also the reason that we could not use Bloom's taxonomy (Bloom et al., 1956)—if a student has previously encountered a question similar to the one he or she is asking, then a higher order question may turn into a lower order question (Dori & Herscovitz, 1999). Our sample includes specific, stand-alone questions

**TABLE 1**
**Examples of Questions Classified According to Spontaneous vs. School-Related Motivation for Raising the Question and to Field of Interest**

| Motivation[a] | Field of Interest[b] | Example (Class, Gender, Country of Origin)[c] |
|---|---|---|
| Spontaneous | Physics: Modern physics | Hand-held dynamo particle accelerator: could an accelerator like this be built easily? I think I would like to play with my own electron beam. (10–12, m, US) |
| Spontaneous | Chemistry: Thermodynamics | When you boil water and you put in macaroni, why does it stop boiling? (4–6, US) |
| Spontaneous | Nature of science | Is biology an actual science? Why? (10–12, f, UK) |
| Spontaneous | Earth sciences: Environment | What makes dust in the air? I'm just curious because I see so much dust in my room, I was wondering where it came from. (10–12) |
| Spontaneous | Astrophysics | Does a black hole lead to another galaxy? (7–9, US) |
| School related | Biology: Botany | I need help on a science fair. I need to know if talking to your plant has an effect on its growth. |
| School related | Physics: Mechanics | Will an egg float higher in Salt Water, Sugar Water or, Normal Water? This is an experiment I am performing for school. Please email me ASAP (4–6, m, US) |

[a] Questions were assigned to the "school-related" category only if they explicitly referred to a school assignment, such as a science fair project, report, homework. All other questions were classified as spontaneous. Note that some school-related questions may have been mistakenly assigned to the spontaneous category.

[b] The first word represents the category (out of eight total) and the second, the subcategory (out of 58 total).

[c] Numbers represent grade level, f = female, m = male, US = United States, UK = United Kingdom. Some questions do not contain all the background variables.

generated by knowledge-deficient mechanisms. This was also the reason we could not use the Scardamalia and Bereiter (1992) classification of basic information or wonderment questions. In our case, all of the spontaneous questions were wonderment questions.

*Order of the Requested Information.* A modified typology, based on one defined by Dillon (1984), was used to classify questions according to a gradual increase in the cognitive level required to answer them (Brill & Yarden, 2003): (1) "Properties"—answers to questions in this category describe the properties of the subject in question; (2) "comparisons"—answering questions in this category requires a comparison between the subjects outlined in the question; and (3) "causal relationships"—answering questions in this category requires finding the relation, correlation, conditionality, or causality of the subjects in question. Usually, questions from the properties category refer to one variable, whereas questions from the comparisons and causal relationships categories refer to at least two variables. For examples of the application of the categories in this coding scheme, see Table 2.

*Type of Information Requested.* A typology influenced by Bloom's taxonomy (Bloom et al., 1956) and Bybee's classification for research questions (Biological Sciences Curriculum Study, 1993) was developed. The typology describes the nature of the question, and the knowledge it generates, along a gradually increasing cognitive-level continuum. The lowest category, "general request for information," includes questions that did not ask for specific answers but for information in general. The second category consists of requests for "factual" information. The third category consists of requests for "explanatory" information, with basically "why" and "how" questions. The fourth category, consisting of questions asking for "methodological" information, has to do with scientific ways of finding things out and with scientific and technological procedures. The highest categories were "predictions"—cases in which the asker described an experiment and asked what the results would be, and requests for "open-ended" type of information dealt with opinions, controversial themes, and futuristic questions that science cannot answer for the time being. For examples of the application of the categories in this coding scheme, see Table 2.

### Reliability

Classification and categorization of 150 of the questions used in this study were performed independently by two researchers. The concordance of classification between researchers ranged from 84% to 98% for the different coding schemes. To test for internal consistency of the data, a modified split-half test was performed: random halves of the data (odd and even observations) were compared. A consistency was found in the distribution of all variables between the two halves.

### Statistical Analysis

Unless otherwise indicated, a two-tailed Pearson chi-square test was used to calculate probabilities. Not all the inquirers provided their full details; therefore, sample sizes differ from graph to graph and are indicated by *n* values. Post-hoc multiple comparisons in sample proportions and Goodman's simultaneous confidence-interval procedure (Marascuilo & McSweeney, 1977) were used to find significant differences within proportions after the chi-square test.

TABLE 2 Examples of Questions Classified According to Order and Type of Information Requested

| Order[a] | Type[b] | Example[c] |
|---|---|---|
| Properties | Factual | How much, approximately, does an ant weigh? (4–6, f, US) |
| Properties | Open ended | What is mind? Does every living being have a mind? (4–6, Oman) |
| Properties | General request for information | Have there been any new discoveries on Mars recently? I'm just interested in Mars and I just wanted to know what is going on that planet!! (10–12, US) |
| Comparisons | Factual | What is the difference between Shooting stars and regular stars? (4–6, f, US) |
| Comparisons | Methodological | The way I know, I think there are relations between blood types to personalities of people. I would like to know more about this subject, but since most of the people do not know their blood types, how could I tell the relation? (10–12, m, US) |
| Causal relationships | Prediction | Will my moving of things outside the tank (i.e. furniture) have as great of an effect on the fish as rearranging gravel? (7–9, f, US) |
| Causal relationships | Factual | If a girl straightens her hair every day what will happen to her hair? Will it affect hair follicles? (7–9) |
| Causal relationships | Explanatory | How does the size of a balloon affect how loud it pops? (7–9) |

[a] Order of information requested was classified into properties, comparisons, or causal relationships, as detailed in the Methodology section.

[b] Type of information requested was classified into requests for information, "factual," "explanatory," "methodological," "predictions," and "open ended," as detailed in the Methodology section.

[c] Numbers represent grade level, f = female, m = male, US = United States, UK = United Kingdom. Some questions do not contain all the background variables.

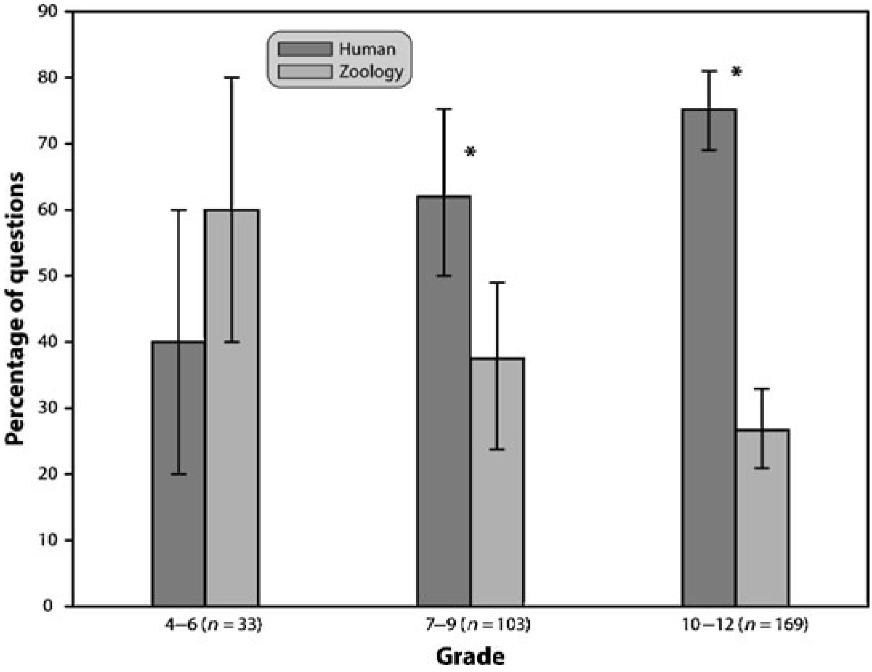

**Figure 1.** Percentage of zoology and human biology questions among three age groups. Overall differences were found to be significant at $p < 0.0005$. Significant differences of $p < 0.05$ between the relative number of zoology and human biology questions are marked with an asterisk.

## RESULTS

To characterize children's interests in science, their self-generated questions were collected from a Web-based Ask-A-Scientist service.[8] The questions were analyzed with reference to four different coding schemes: field of interest, spontaneous versus school-related motivation for raising the question, and type and order of information requested. We also considered the relationship between the four different schemes and the available background knowledge about the children who sent the questions.

### Field of Interest

In a basic breakdown of the questions ($n = 1555$) analyzed by field of interest, biology proved more popular than the other sciences, and was the focus of 44% of the questions. This popularity reflects findings from previous studies (Murray & Reiss, 2005; Qualter, 1993). Biology was followed by chemistry (21.9%), physics (12.9%), technology (7.5%), earth sciences (5.9%), astrophysics (5%), NOS (1.1%), and mathematics[9] (0.5%), while 1.4% of the questions could not be classified into a scientific field of interest. The subcategories of each field of interest are detailed in the Appendix, in their order of popularity.

Many of the questions in the field of biology were embedded in the context of either human biology or zoology. Our analysis indicated that the relative frequency of zoology questions decreased with age, as the proportion of questions relating to human biology increased ($\chi^2 = 15.4$, $p < 0.0005$) (Figure 1). The interest of high school students in human

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[8] http://www.madsci.org

[9] MadSci Network is an educational science site, and does not encourage math questions.

biology is well attested to by a number of studies, including research done in England (Osborne & Collins, 2001) and Israel (Tamir & Gardner, 1989). The increased interest in human biology with age might be explained by the approach of puberty in this age group. A similar increase in interest with age has been noted among the spontaneous questions of Israeli elementary and junior high school students (Baram-Tsabari & Yarden, 2005).

### Spontaneous Versus School-Related Motivation for Raising the Question

Children asked more school-related questions as they got older: 10%, 33%, and 57% of the questions were school related for elementary, junior high and senior high schools, respectively. The same trend was found in school libraries, where students placed less spontaneous queries with age (Gross, 2001).

The spontaneous scientific interests of children were found to be different from their school-related questions (Figures 2 and 3). In all age groups, astrophysics was more prevalent among children's spontaneous questions ($p < 0.01$) (Figure 2). This interest in space science mirrors existing literature about students' interests (Osborne & Collins, 2001; Sjøberg, 2000). Chemistry, on the other hand, was far more prevalent among children's school-related questions than spontaneous ones ($p < 0.01$) (Figure 2). Biology was the most popular subject, among both spontaneous and school-related questions.

The major fields of interest do not reveal the whole picture. When studying interest, the devil is in the little details. Therefore, we compared students' spontaneous versus school-related interest in the different subcategories (Figure 3). Biology, which dominated the same percentage of questions in both groups, revealed much more diversity when broken down into topics. When analyzing biological questions in topics that appeared more frequently (as detailed above), we realized that "anatomy and physiology," "sickness and medicine," and "genetics and reproduction" were all characterized by relatively more spontaneous than school-related questions. At the other end of the spectrum, "botany and mycology," "microbiology and virology," and "cell biology" yielded many more teacher- and textbook-generated questions than spontaneous ones. "Ecology" and "neurology and the mind" were almost equally distributed among both types of questions and generated a relatively high number of them.

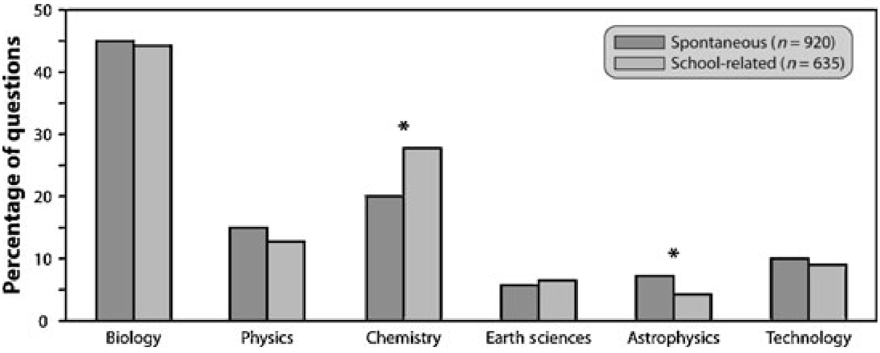

**Figure 2.** Students' spontaneous vs. school-related scientific interests: an overview. Students' questions were classified according to their field of interest. Percentage is calculated out of the total spontaneous ($n = 920$) or school-related ($n = 635$) questions. Undistinguished ($n = 22$), nature of science ($n = 17$), and math ($n = 7$) questions are not shown due to their relatively small number. A significance of $p < 0.01$ is marked with an asterisk.

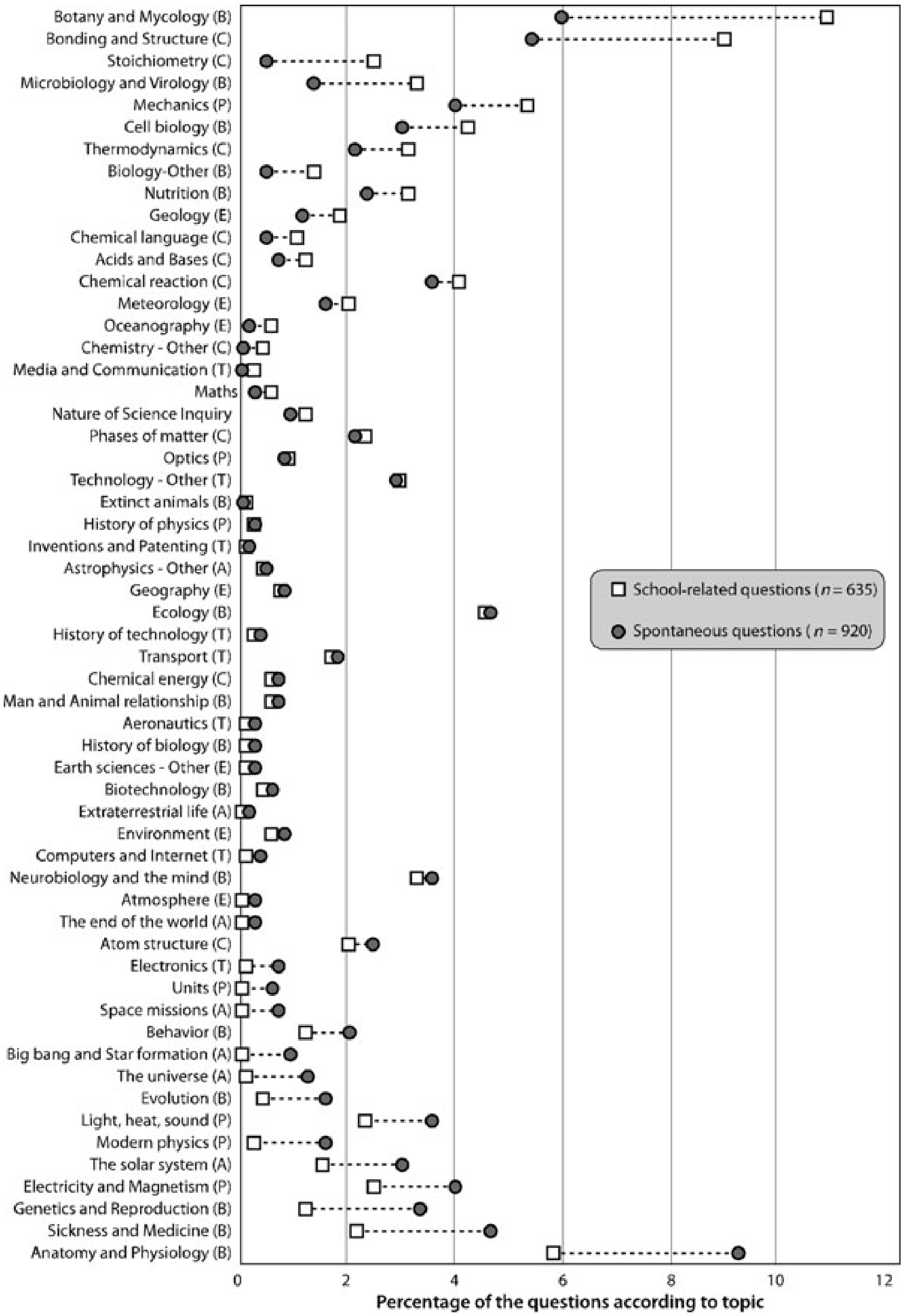

**Figure 3.** Students' spontaneous vs. school-related scientific interests in specific topics. Students' questions were classified into one of 58 subcategories, according to their field of interest (see Appendix). Percentage is calculated out of the total spontaneous ($n = 920$) or school-related ($n = 635$) questions. Undistinguished ($n = 22$) questions are not included. The subcategories are listed according to the gap between the number of spontaneous and school-related questions. B: biology; C: chemistry; P: physics; E: earth sciences; A: astrophysics; T: technology.

A similar analysis conducted on the chemistry questions revealed that the most popular subcategories (e.g., "bonding and structure") were all school related. All of the astrophysics topics, on the other hand, were mostly spontaneous. Among earth science and technology topics, there were no major gaps between the number of school-related and spontaneous questions. Physics subcategories, however, appeared at both ends of the scale. "Mechanics" provoked more school-related questions than spontaneous ones, whereas "electricity and magnetism," "modern physics," and "light–heat–sound" were the source of authentic childish interest, yielding spontaneous questions.

## Cognitive Level of the Questions

We subsequently analyzed the cognitive level of the questions submitted to the MadSci Network. The questions studied here were found to present higher order of requests for information than reported in the literature, using two separate classification schemes. Among the 920 spontaneous questions, 77% asked properties type of questions that mentioned only a single variable, whereas the remainder asked for comparisons or causal relationships between two variables, i.e., inquiries of a higher cognitive level. The order of information requested increased with age, as students in secondary school raised more comparison and causal relationship questions (25.3% among 7th–9th graders, 23.6% among 10th–12th graders) compared to elementary school students (13.8%). In contrast, studies in high school biology classes have found that fewer than 6% of the students' questions deal with more than one variable (Brill & Yarden, 2003).

Moreover, among the 920 spontaneous questions, only 54% were general requests for information and questions of the factual type, 35.6% were explanatory, and 5.3% were methodological. Predictions and open-ended questions made up the remaining 5.1%. This picture of children's questions is far more encouraging than the one portrayed by studies conducted within science classes, which report that only 14% of the questions reflect curiosity, puzzlement, skepticism, or speculation, while all the rest are simple factual or procedural questions (Chin, Brown, & Bruce, 2002). These desirable traits characterized all of the spontaneous questions studied here.

## Gender-Related Findings

***Gender Split.*** Surprisingly, girls asked most of the questions in this study (56.4% overall). This female dominance was apparent in questions sent from the United States, Canada, and the United Kingdom, but not in those from other countries surveyed in this research. This female majority contradicts previous female-to-male ratios obtained from a scientific Internet site based in Italy (Falchetti, Caravita, & Sperduti, 2003), a UK-based science line (K. Mathieson, personal communication, April 2, 2004), and science and technology questions at an Israeli Web site (Baram-Tsabari & Yarden, 2005). Furthermore, females were previously shown to be less likely than males to use media that foster informal learning about science (National Science Foundation, 2000; Nisbet et al., 2002), and to take part in extracurricular science experiences (Greenfield, 1998). It was found that although boys have more formal and out-of-school experience using computers and the World Wide Web (Kafai & Sutton, 1999; Shashaani, 1994), more girls preferred this type of learning over traditional classroom-based science learning (Leong & Al-Hawamdeh, 1999).

Nevertheless, a significant decrease ($p < 0.05$) in the number of American girls submitting science questions occurred during the transition from junior to senior high school

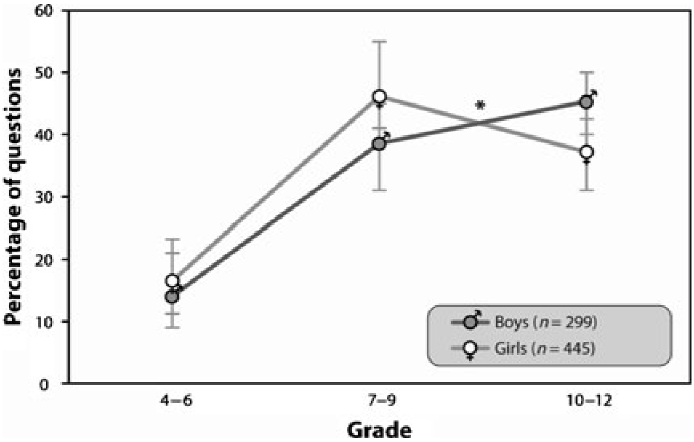

**Figure 4.** Percentage of American boys' and girls' questions among three age groups. The overall differences between the proportions of boys and girls in the different age groups are significant at $p < 0.05$. The different trends of girls' and boys' questioning behavior among the 7–9th and 10–12th grade groups are the reason for this significance according to a post-hoc test. The relative drop in the girls' number from the 7–9th to 10–12th grade groups was found to be significant at $p < 0.05$ and is marked with an asterisk.

(Figure 4). This finding mirrors previous research in which American girls' attitude to science was found to become increasingly negative with age (Kahle & Lakes, 1983), as well as studies carried out in Israel (Friedler & Tamir, 1990; Shemesh, 1990).

***Fields of Interest.*** Consistent with previous studies (Dawson, 2000; Friedler & Tamir, 1990; Jones et al., 2000; Sjøberg, 2000; Stark & Gray, 1999; Zohar, 2003), the girls in our sample found physics to be significantly less interesting than the boys ($p < 0.05$), whereas biology was of greater interest to girls than boys ($p < 0.025$). This polarized trend was apparent in both school-related and spontaneous questions, suggesting that girls and boys follow certain content-related stereotypic interests in both school and self-guided activities with respect to science education.

To refine our analysis, we compared girls' and boys' interests in the various subcategories of the fields of interest (Figure 5). The girls' preference for a biological context was apparent: among their top ten topics, eight belonged to the biological field of interest, one to chemistry, and one to astrophysics. Boys, on the other hand, had more diverse interests, with their top ten made up of four physics, two technology, two biology, one chemistry, and one astrophysics topic. This list of gender-related learning interests fits well with known stereotypic preferences for specific topics (Busch, 2005; Jenkins & Nelson, 2005; Jones et al., 2000; Sjøberg, 2000; Stark & Gray, 1999; Taber, 1991).

***Spontaneous Versus School-Related Motivation for Raising a Question.*** Girls asked many more school-related questions than boys: 45.7% of the girls' questions were school related, compared with 36.5% of the boys. This trend might be explained by Simpson and Oliver's (1985) findings that American 6th- to 10th-grade females are significantly more motivated than boys to attain high achievements in science, although exhibiting less positive attitudes toward it.

We found no gender-related difference in the type or order of information requested.

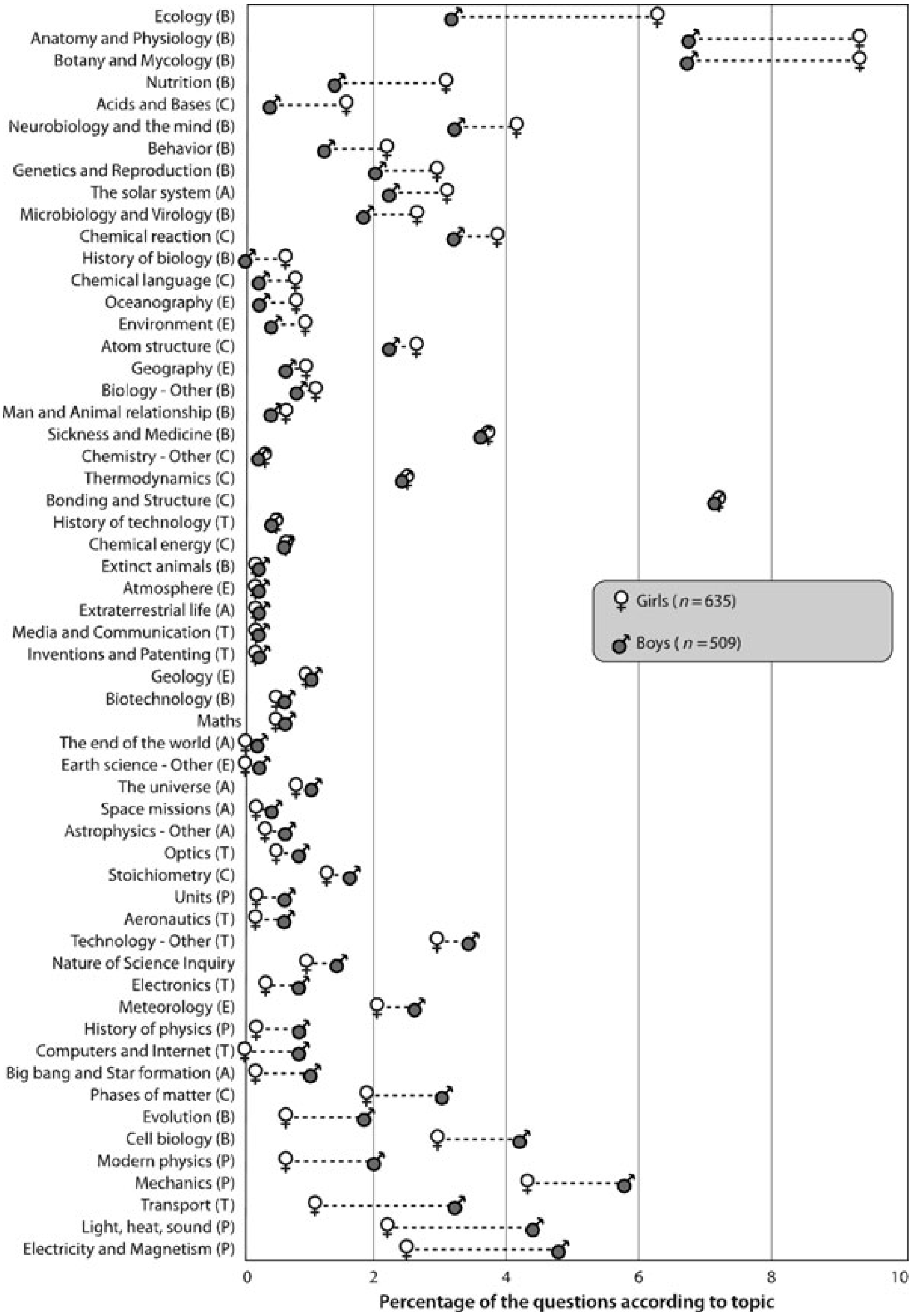

**Figure 5.** Boys' and girls' interest in various scientific topics. Students' questions were classified into one of 58 subcategories, according to their field of interest (see Appendix). Percentage is calculated out of the total girls' ($n = 635$) or boys' ($n = 509$) questions. Undistinguished ($n = 22$) questions are not included. The subcategories are listed according to the gap between the number of girls' and boys' generated questions. B: biology; C: chemistry; P: physics; E: earth sciences; A: astrophysics; T: technology.

## DISCUSSION

The purpose of this study was to investigate students' interests in science using their self-generated questions. We argue that there is considerable promise in using students' self-generated and primarily spontaneous questions to enhance the attractiveness and relevance of science curricula. The methodology used here may provide a rapid and consistently up-to-date way of assessing children's interests while avoiding adult-generated views. Some limitations of this methodology are discussed further on.

Some of our results confirmed and reinforced what is already known about children's interests, using a different data source and methodology. However, this study provides new insights into topic-specific differences between spontaneous and school-related interests in science; the higher cognitive level of children's questions in this sample compared to classroom settings; the dominance of female participants in a free-choice science-learning setting, and the females' tendency to ask more school-related questions than boys; and finally, the persistence of girls' and boys' stereotypic interests among both the spontaneous and school-related questions. The significance of these new insights is discussed further on.

An important observation of this study is the recurring inconsistency between students' spontaneous (intrinsically motivated) and school-related (extrinsically motivated) interests. There is evidence that intrinsic motivation can promote learning and achievement better than extrinsic motivation (Pintrich & Schunk, 2002). Therefore, it might prove pedagogically beneficial to respond to children's interests by incorporating into school science, topics which are of spontaneous interest to children, such as "the solar system," "modern physics," "evolution," and "the universe," which are currently underrepresented in many science curricula.

Our findings suggest that students can raise questions reflecting a high cognitive level on their own, but may feel less comfortable or encouraged to do so during science class. Another interpretation is that students may have more time to reflect and compose their questions in an online setting than during science class. It should be borne in mind, however, that the student population submitting questions to the MadSci Network may have a higher level of motivation to seek sources outside the classroom for science learning, thus providing a potential bias in our analyses.

The female dominance found among the MadSci responders suggests that online science education Web sites provide an attractive science-learning environment for girls. It is possible that the varying data between different countries highlight a dynamically changing landscape as girls gradually gain more access to the Internet and acquire the skills needed to use it to satisfy their scientific curiosity and obtain assistance with their science schoolwork. We anticipate that further investigation in this area will elucidate the benefits of online forums for science education in bringing equality to previously gender-biased areas of scientific interest. We cannot ignore, however, the sad fact that even in this seemingly attractive setting, the number of questions posed by American girls dropped upon their entering senior high school.

When basing new material on children's interests, it is important to pay attention to gender differences in preferences (Daiute, 1997). We found significant differences between girls' and boys' interests, with girls generally preferring biological topics. The two genders kept to their stereotypic fields of interest in both their school-related and spontaneous questions, hinting that the differences in interest described in the literature relating to school-science settings may also be relevant to free-choice settings.

However, there are also topics which appeal to both sexes, and arouse spontaneous interest as well. Therefore, it seems possible to teach scientific concepts and ideas in the context of topics which are not profoundly preferred by boys, but rather preferred by girls or equally attractive to both genders (Hoffmann & Haussler, 1998; Krapp, 2000; Sjøberg, 2000). Our study identified a few equally attractive topics, such as health issues, atom structure, and chemical bonding and structure, and a few science subjects which are very popular among girls, such as ecology, anatomy, botany, nutrition, and neurology. Using these topics as the context for science learning could prove beneficial in the process of mainstreaming science education.

## Research Limitations

Although the study described here sheds some light on what interest children, caution is needed in identifying implications for school science education. The self-selecting sample used in this research does not represent all children. It represents a group of children that might be more interested in science and have more access to resources than the child population as a whole. Students who are not motivated to learn science are not represented in this self-selecting sample at all. Other children that may be very interested in science but do not send questions are also not represented. Therefore, the opportunistic nature of the sample places some limitations on the validity of our results.

Another setback of this research lies within the criteria for coding school-related questions. Since only questions that explicitly stated a school-related motivation for seeking an answer were coded as "school related," it is very likely that some school-related questions were mistakenly coded as spontaneous ones. As a consequence, the difference between school-related and spontaneous interests might be somewhat different than what is reported here. Furthermore, all of our findings are based on observations and their interpretation. For ethical reasons, we could not ask our subjects to explain their true intention in raising the question, their aim or their motivation. All of these were inferred from the wording of the written text generated by the child. We might have misunderstood the askers' meaning in some cases, a problem that might be partially addressed in the future by interviewing children who send science questions to Ask-A-Scientist sites.

Other problems are independent of our specific research design, but are intrinsic to the agenda of the pupil's voice movement. What role should the pupil's voice play in determining curriculum content? Should we teach children what they wish to know now, or what they ought to know in order to become scientifically oriented citizens in the future? And even if we pay attention to children's interests, how can one be interested in something one does not know exists? It is evident from examining Figure 3 that most popular school-related topics yielded a relatively high number of spontaneous questions as well. Some of these questions were probably school-related questions in disguise, but surely not all of them. These children's intrinsic motivation to know might have been evoked by their formal or informal science education.

Finally, we are faced with the big question of trying to implement results gathered in a free-choice science-learning setting into formal schooling. Once those topics become compulsory in the classroom, will not they lose their free-choice appeal? All of these setbacks need to be addressed in the process of using students' individual interests in science education.

## Implications for Teachers

Although individual interests have a significant effect on learning, their use in educational settings may be problematic. Catering to the personal interests of individuals in the classroom might be an extremely time- and effort-consuming task, especially if the classes are large (Hidi & Anderson, 1992). However, a few steps have already been taken down the path of incorporating students' interests into the science classroom. Gallas (1995) used her students' questions to construct a curriculum which emerged from children's questions. But even this luxurious solution answered just a few of the children's questions, and in a very specific area. It is by no means obvious that it can be generalized to other areas of science education or indeed used to construct a national science curriculum.

Students' interests can provide a positive instruction tool within the standard science curriculum as well, since topics that fascinate children can be related to subject matter to provide a base for new knowledge. Daiute (1997, p. 329) instructs teachers on how to recognize and use those topics in the classroom:

> Children tend to explore such [fascinating] issues through the details of specific events rather than to state explicitly that they are interested in "justice," "life and death," or "identity," so we need to be astute listeners to the underlying themes of children's talk. When such topics emerge as recurrent themes underlying children's conversations, it is the optimal time to explore such issues in relation to subject matter in your curriculum.

An expert teacher can use students' individual interests as opening points or triggers for the study of less popular subjects which are required by the curricula. There are also existing pedagogical tools that take into account student's interests, such as science fairs and project-based learning, which allow students to create their own research questions within a given topic (Ching, Kafai, & Marshall, 2000; Fallik, Eylon, & Rosenfeld, submitted).

Many of the Ask-A-Scientist sites have an archive, which usually presents a frequently asked questions (FAQs) section. Teachers may consider these repeated questions to be of general interest to children, and they can search the archive for children's questions on the subject they wish to teach, at the appropriate age level.

Another implication of this research would be to prompt science teachers to make more room for students' questions. Questions are an important part of the ongoing scientific research process and have an important educational role (Biddulph et al., 1986; Scardamalia & Bereiter, 1992). Our results indicate that students are able to pose science questions in informal settings, and it would be educationally beneficial if they would use this ability in classrooms as well.

### Implications for Curriculum Developers

Adults construct the curriculum based on their notions of what appeals and is important to children, but Seiler (2001) argues that standards-based curricula will continue to fail in urban settings of poverty because they have not included the voice of the students. We believe that not only students from low social classes can benefit from a more student-centered type of curriculum. If curriculum relevance is to have any meaning, it cannot exclude the views of the students themselves (Jenkins & Nelson, 2005). Therefore, more emphasis should be placed on what students wish and ask to know while constructing the curriculum which serves them.

This might be achieved by choosing preferable contexts for teaching scientific concepts and ideas. School level "cell biology," for example, can be taught using examples of organisms from all kingdoms. Our results indicate that using a human context may prove to be less of a turn off.

### Implications for Interest Researchers

The methodology presented here may extend the context in which children's interests can be investigated. Children's science interests, as inferred from their questions to Web sites, could ultimately inform classroom science teaching. However, it seems that classifying the questions into 58 topics is not sufficient if we wish to use the power of students' interests in curriculum development. Subcategories such as "sickness and medicine" or "anatomy and physiology" might be too broad. We need to focus at a higher resolution, learning about students' interests in specific issues, species, illnesses, and technological breakthroughs in order to use them as "hooks" within the curriculum. This goal can only be achieved by using samples of tens of thousands, rather than thousands of questions. These data exist in the archives of many Ask-A-Scientist sites and can be used for such analyses, with the cooperation of the sites' operators. Such future cooperation between researchers and Ask-A-Scientist site operators could make the data gathered in them more valuable for interest research. For example, upon question submission, some questions might be added regarding the scientific basis for the question, its relation to school, and the motivation for raising it. These types of questions might also help the scientists who answer the questions.

This methodology can also be used to track the development and shift in interest in a specific field or topic, by using a few sites which cater to different age levels. Another option is to compare the science interests of children from different cultures, by using non-English language Ask-A-Scientist sites or by comparing questions from different countries in English-based sites, when this kind of data is available. Once a very large corpus of data is gathered from various databases, we believe that the power of clustering analysis can be used to unearth unexpected patterns of age, gender, and country-of-origin effects on the scientific interests, motivations, and cognitive levels of the questions. Finally, it is important to emphasize that all of the information regarding children's science interests can be used by informal science educators to make free-choice science-learning opportunities more engaging and attractive to children.

## APPENDIX

**Biology**

- Botany and mycology
- Anatomy and physiology
- Ecology
- Sickness and medicine
- Cell biology
- Neurobiology and the mind
- Nutrition
- Genetics and reproduction
- Microbiology and virology
- Behavior
- Evolution
- Other
- Man and animal relationship
- Biotechnology
- History of biology
- Extinct animals

**Earth Sciences**

- Meteorology
- Geology
- Geography
- Environment
- Oceanography
- Other
- The end of the world
- Atmosphere

**Astrophysics**

- The solar system
- The universe
- Big bang and star formation
- Other
- Space missions
- Extra-terrestrial life

**Physics**

- Mechanics
- Electricity and magnetisms
- Light–heat–sound
- Modern physics
- Units
- History of physics

**Chemistry**

- Bonding and structure
- Chemical reaction
- Thermodynamics
- Atom structure
- Phases of matter
- Stoichiometry
- Acids and bases
- Chemical language
- Chemical energy
- Other

**Nature of science inquiry**

**Technology**

- Other technologies (low-tech)
- Transportation
- Optics
- Electronics
- History of technology
- Computers and Internet
- Aeronautics
- Inventions and patenting
- Media and communication

**Math**

**Undistinguished**

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