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A Shadow Curriculum: Incorporating Students' Interests into the Formal Biology Curriculum

Galit Hagay · Ayelet Baram-Tsabari

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Abstract Students have been largely ignored in discussions about how best to teach science, and many students feel the curriculum is detached from their lives and interests. This article presents a strategy for incorporating students' interests into the formal Biology curriculum, by drawing on the political meaning of "shadow government" as alternative policies developed by parties not in office. A "shadow curriculum" thus reflects the interests and information needs of those who have no voice in deciding what the formal curriculum should include, although they are the ones who are most influenced by it. High school students' interests in three Biology topics were identified (n=343) and retested on another student sample (n=375), based on their solicited questions as indicators for interests. The results of this exploratory case study showed that half of the questions asked by students in the areas of genetics, the cardiovascular system and the reproductive system are not addressed by the national curriculum. Students' questions were then expressed in the curricular language of principles, phenomena and concepts in order to create a shadow curriculum. A procedure that could be used by other researchers and practitioners to guide the development of a curriculum that is more aligned with student interests is suggested.

Keywords Pupils' voice · Biology education · Curriculum development · Interest · Students' questions

This manuscript attempts to provide a means for confronting the gap between students' interests in science and the curricula they are required to learn in school science. Incorporating students' interests into science teaching is far from being methodologically and practically straightforward. This study suggests a framework for science teachers and curriculum developers, which includes the following steps: identifying students' interests

G. Hagay · A. Baram-Tsabari (✉)
Department of Education in Technology and Science, Technion, Haifa 32000, Israel
e-mail: ayelet@technion.ac.il

and informational needs, validating their generality, and translating these tokens of relevance into curricular terms.

Literature Review

Pupils' Voice in Science Education

The expression *shadow curriculum* has already been used in several contexts. *Shadow curriculum* have been used in a similar sense to *hidden curriculum* in the environmental education context (Jucker 2002). It was coined to refer to the disparity between stated positions and facts on the ground. Environmentalists used the term to differentiate universities' positions regarding renewable resources from their actual practices (Brown 2005). Likewise, a *shadow curriculum* in bioethics refers to what gets taught incidentally through observation in hospitals and role modeling as compared to material in the bioethics curriculum (Pierce and Paulman 1999). In media literacy, *shadow curriculum* draws attention to a purportedly hidden curriculum involving connections between business, schools and marketing (Brown 2005).

Here we draw on the political meaning of *shadow government* as alternative policies developed by parties not in office. A shadow curriculum[1] thus reflects the interests and information needs of those who have no voice in deciding what the formal curriculum should include, although they are the ones who are most influenced by it—the students.

"When you are under 18, it doesn't really matter what you want. Someone else will tell you what you need, and if you don't agree with him it only shows that you are not qualified to decide for yourself", wrote an Israeli 12th grader. "Someone else tells you when to learn, what to learn and how to learn, but your own interests are called 'a waste of time'" (Idan 2009 p.6).

Researchers involved in educational reform and policy are familiar with this type of argument. Whitehead and Clough (2004) argued that pupils need to be included as stakeholders who shape the implementation of policy and become part of the solution. According to Levin (2000 p. 155), "Even though all the participants in education will say that schools exist for students, students are still treated almost entirely as the objects of reform". The idea that educational reform cannot succeed without greater direct involvement of students in all its facets was also emphasized by Cook-Sather (2002), who recommends attending to the perspectives of those most directly affected by, but least often consulted about, educational policy and practice. "There is something fundamentally amiss", she says, "about building an entire [education] system without consulting at any point those it is ostensibly designed to serve" (Cook-Sather 2002, p. 3 p.3).

Students have been largely ignored in debates about how best to teach science (Wood et al. 2009). In his review "The Student Voice and School Science Education" Jenkins (2006) pointed out that research into students' interests and attitudes seems to have had little general impact on pedagogy (Jenkins 2006). Students are generally regarded as an object of study but not as individuals who can make an informed judgment on what should be taught in school science courses (Jenkins and Nelson 2005).

[1] A syllabus is a document which outlines topics to be covered in a course, while the broader term curriculum encompasses learning outcomes, teaching strategies, and the context in which learning and teaching takes place. By infusing students' input into a syllabus, it is transformed into something that may be better described as a curriculum.

A recent study by Wood et al. (2009) reports how U.S. students are excluded from discussion and planning of their own futures. Their data, collected from many thousands of students and their teachers, show that students and teachers differ not only in their opinions about their class, textbook, and the subject itself, but also in their perceptions about what happens in the classroom (Wood et al. 2009). Teachers believed they were presenting material in ways that were highly relevant to students, but the students merely saw these attempts as "random interjections of miscellany into what was still just abstract and personally irrelevant science" (Wood et al. 2006 p. 429).

Teacher and student values differ as well. Teachers view school science as a preparatory phase, either to educate informed citizens or to train future scientists. Students in general do not view school as preparation for anything useful, but as something they have to deal with at the moment. They tend to judge the experience in terms of interest, fruitfulness, clarity (Wood et al. 2009), and sense of social belonging (Andersson and Linder 2009). Classically, Dewey opposed the future-oriented approach to education because it undermines motivation by diverting the focus from the present interests of the student to preparing for an unknown and vague future. Hence this type of approach requires extrinsic rewards and punishment, because it is divorced from the present interests of the student (Dewey 1916).

Interest and Curriculum Relevance in Science Education

Many interacting factors influence students' achievements and engagement with science education, and by extension the likelihood that they will make science related career choices. This study focuses on the importance of course content and its relevance to students' interests. Declining enrolments in science and technology are very often attributed to the uninteresting and difficult content of science courses (OECD 2006). The Glenn report *Before it's too late* stresses this point, claiming that "we are failing to capture the interest of youth for scientific and mathematical ideas" (The National Commission on Mathematics and Science Teaching for the 21st Century 2000).

Interest is a form of intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, in contrast to extrinsic motivation, which refers to doing something because it leads to a separable outcome, such as praise or avoidance of punishment (Ryan and Deci 2000). Interest is a powerful motivator (Deci 1992), which differs from most other motivational concepts by its content specificity (Krapp 2002). Dewey (1902 p. 15) stresses that "interests are but attitudes towards possible experiences, they are not achievements, their worth is in the leverage they afford, not in the accomplishment they represent".

Basing teaching on students' interests may prove a very beneficial pedagogical strategy, since positive relationships have been reported between interests and a wide range of learning indicators (Pintrich and Schunk 2002; Schiefele 1998). When allowed to pursue their own interests, students participate more, stay involved for longer periods, and exhibit creative practices in doing science (Seiler 2006). Nevertheless, in the current era of high-stakes testing, teachers are often forced to use prescriptive curricula and are certainly not advised to follow students' interests or concerns (Schltz and Oyler 2006).

Consequently 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 and Osborne 1998). One key aspect of school science that is reported as unattractive to 16-year-old students is the lack of discussion of topics of interest (Osborne and Collins 2001). The achievement-motivation problem might be accounted for in terms of the discrepancy between the curriculum and students' natural interests in learning in elementary (Baram-Tsabari and Yarden 2005), middle (Mcphail et al. 2000) and high school (Baram-Tsabari et al. 2006; Kwiek et al. 2007).

Teachers and curriculum developers should be encouraged to determine students' interests, and relate these interests to subject matter to provide a base for new knowledge (Kidman 2009). Similarly, Christidou (2006) argues that science curricula should become more appealing to students by integrating topics and experiences that are interesting and relevant to them.

Attempts have been made to develop relevant and interesting science curricula, learning materials and activities. However, relevance has usually been defined with the interests of adults rather than young people in mind (Jenkins 2006). A context designed to legitimize learning from the students' perspective, by making their learning intrinsically meaningful, for example, was chosen by certain curriculum developers (Bulte et al. 2006). Edelson and Joseph (2004) designed learning activities that exploit the power of usefulness as a form of interest. However, the choice of context was based on the perceived usefulness to the environment designer or on his/her attempts to anticipate users' interests. Chamany et al. (2008) attempts to make Biology learning relevant to students was based on a variety of historical and contemporary resources, but not on students' interests. Adults construct the curriculum based on their notions of what appeals and importance to students. However if curriculum relevance is to have any meaning, it cannot exclude the views of the students themselves (Jenkins and Nelson 2005).

Several science educators have incorporated students' authentic interests into their educational initiatives. During the last decade several science educators have drawn on students' voices and knowledge to direct science leaning, mainly in low-income urban schools (Basu and Calabrese Barton 2007; Basu 2008; Calabrese Barton and Tan 2009; Furman and Barton 2006; Seiler 2001). This strategy increased students' engagement and understanding, and was a valuable tool in the process of students' identity formation. Fusco (2001) who involved urban youth in a community-based science project, judged this science to be relevant because "(a) it was created from participants' concerns, interests, and experiences inside and outside science, (b) it was an ongoing process of researching and then enacting ideas, and (c) it was situated within the broader community" (p. 872). Upadhyay (2006) claims that urban students have to see some kind of connection between their science learning and experiences, and teachers have to create an environment in the classroom where such connections can be made. Support for this claim may be found in a recent randomized field experiment in which high school students were instructed to write essays discussing the connections between their lives and what they were learning in science class. The relevance intervention resulted in higher course grades and more interest in science for students with initial expectations of low success (Hulleman and Harackiewicz 2009).

Sixth grade students who were working in inquiry settings that reflected their primary content area of interest (either science, drama, animals, or movement) experienced higher levels of affect and activation than their peers who were not engaged in content-based activity settings of their first choice (Mcphail et al. 2000). This study found that sixth grade students can reliably describe their interests in learning, and that the use of these interests in the design of curricula can increase student engagement in learning (Mcphail et al. 2000).

In the context of higher education, Denofrio et al. (2007) used undergraduates' interests in everyday life as a starting point for instruction in Biology and Chemistry. Rather than changing existing courses, they worked within the existing infrastructure. Using mentoring, and mimicking scientific research groups they helped students to navigate between the thousand of courses offered by the university, assisting them in identifying courses and research groups that matched their interests (Denofrio et al. 2007). Hansmann (2009) used graduates' judgment to evaluate the compatibility of sustainability-oriented university curricula with workplace demands and to direct a curriculum reform.

Students' Interest in Biology

Heightening curriculum relevance and building on students' interests are cross-disciplinary concerns. The present study is restricted to the Biology classroom, which is the most popular science subject among students and adults (Baram-Tsabari and Yarden 2005; Baram-Tsabari et al. 2006; Baram-Tsabari et al. 2009b; Baram-Tsabari and Yarden 2009c, 2010; Dawson 2000; Falchetti et al. 2007; Murray and Reiss 2005; Osborne and Collins 2001; Qualter 1993), and even more so among female students and adults. Key findings on female and male students' interest in biology, the changes in interest in biology between age groups and the inconsistencies between biology students' and teachers' interests in the field are summarized below.

Differences exist between the topics that males and females find interesting within Biology: according to results from the international Relevance of Science Education [ROSE] project in Denmark (Busch 2005), England (Jenkins and Nelson 2005), and Norway (Schreiner 2006), girls are most interested in biological topics concerning health, the mind and well-being. Results from the ROSE project in Finland indicate that boys are more interested than girls in basic processes in Biology, whereas girls find human Biology and health education more interesting than boys (Uitto et al. 2006).

Interest in Biology changes with age: as interest in Zoology decreases, interest in human Biology increases (Baram-Tsabari and Yarden 2005, 2007; Baram-Tsabari et al. 2006). The increased interest in human Biology among adolescents is probably due to the approach of puberty and the related increasing interest in one's body. Adults seem to be more interested in human Biology because they are more concerned with health issues and many of the questions raised about human Biology refer to the asker himself/herself (Baram-Tsabari and Yarden 2009c). Older pupils' interest in human Biology is well attested to by a number of studies, including some conducted in England (Osborne and Collins 2001), Israel (Tamir and Gardner 1989) and Poland (Stawinski 1984). Within younger age groups, Haussler and Hoffmann (2002) who studied 11–16 year old students' interests in Physics, found that anything embedded in the context of the human body is attributed high interest scores.

Kidman (2009) provides direct evidence that teachers have different interests in Biology than their students: Australian students responded to a list of topics in modern biotechnology, indicating which topics they would like to learn about. The students were most interested in topics that might have personal relevance or ideas that involved hands-on experimentation, including cloning their own plant, gene profiling for paternity, testing natural antibiotics, altering human gene codes and extracting DNA. Their teachers, on the other hand, were most interested in teaching different topics, such as the impact of GM crops on environment and health, ethics in media articles, and a GM cotton which produces its own insecticide (Kidman 2009).

Research Aim

Kidman's (2009) findings, in concert with the results presented by Wood et al. (2009) suggest that teachers' interests in Biology do not accurately represent the interests of their students. More emphasis should therefore be placed on what students want to know in order to create a relevant biology curriculum. This measure could contribute to changing the absurd situation described above, where students' interests are termed 'a waste of time' (Idan 2009)

Previous research tells us quite a bit about students' interests in science, and specifically in Biology. How can these latent data be converted into functional knowledge with pedagogical implications? Suggesting a framework for identifying students' interests and informational needs, validating their generality, and translating these tokens of relevance into curricular terms, are the main goals of this study. This framework will be demonstrated in the context of Israeli high school students' interests in three Biology topics, although it may be applicable for other disciplines and age groups as well. An application of this framework is the creation of a shadow curriculum which provides an alternative content and emphasis to the formal science curriculum that reflects students' interests and information needs and enables teachers to incorporate them into their teaching.

Methodology

Data Collection: Approach

Tapping into the honest and natural curiosities of children is not simple from a methodological standpoint (Mielke and Chen 1983). Students' scientific interests are traditionally identified by questionnaire-based methods which involve asking students to tick boxes in response to a series of prepared questions or topics (e.g. Christidou 2006; Dawson 2000; Qualter 1993; Sjøberg and Schreiner 2008). A closed questionnaire gives quick and clear cut quantitative answers: is this topic interesting to many students or is it perceived as boring? However it relies on the basic assumption that the range of choices presented in the questionnaire is in fact interesting to students. These lists of topics are based on adult-centric views of what subjects should be meaningful to the students, and may not adequately represent their interests.

Learner-centered research approaches to identifying students' interests in science include focus groups (Osborne and Collins 2001), a student-led review of the science curriculum (Murray and Reiss 2005), brainstorming sessions, and individual and group interviews (Mcphail et al. 2000). Self-generated science questions are also used as indicators of interest (Baram-Tsabari and Yarden 2005; Baram-Tsabari et al. 2006, 2009b; Baram-Tsabari and Yarden 2007, 2008, 2009c, 2010; Baram-Tsabari and Kaadni 2009a; Cakmakci et al. 2009; Falchetti et al. 2007; Yerdelen-Damar and Eryılmaz 2010). By asking questions, students express the foreign words of science with their own words, experiences, and previous knowledge, while searching for the authority of science as a structured body of public knowledge (Aguiar et al. 2009). Through studying students' questions, one can learn what students are interested in knowing about a given topic (Chin and Osborne 2008).

Students' questions were chosen as a data collection method in this study because this method is open-ended, learner centered, and researchers do not impose their views on students. Asking questions is also a creative activity which may result in a diversity of contexts and associations that cannot be predicted in advance. For a review of research on students' questions see Chin and Osborne (2008), and for a discussion of students' questions as a data source about their interests see Baram-Tsabari et al. (2009c). Questions were collected using anonymous written questionnaires to allow all students to raise their questions without fearing ridicule or exposure to their peers. The classroom was chosen as the setting for data collection since the end product of this study was the transformation of the curriculum, thus making the school setting the most authentic data collection environment. Focusing students on only three Biology topics made it possible to collect a critical mass of questions in specific domains, creating a reasonably large sample of questions.

Data Collection: Procedure

The students' input was collected in a two-step procedure:

Step 1 *Probing questionnaire.* students' questions were collected anonymously using prompts asking them to write questions about three biological topics and explain why they found them to be interesting. The questionnaires were also used to collect background data that included respondents' grade, gender, elective courses, self-reported level of interest in each of the three topics and Biology in general, as well as level of attentiveness to popular science (Appendix 1).

Step 2 *Generalizing questionnaire.* The responses to this questionnaire were used to generalize the findings, allowing us to assume that a question raised by a few students was indeed interesting to many others as well. Over 550 students' questions were collected from the probing questionnaire. Fifty six frequently asked questions, which represented the three biological topics, were extracted from this sample. A closed questionnaire was constructed based on these questions. It asked the respondents to rate their interest in each question on 1–5 point Likert-type scale and to choose a reason for their interest in the question from a list of nine options. After a pilot study involving ten students, the questionnaire was shortened to 36 questions. The questionnaires were also used to collect the same background data as in step 1 (the questionnaire prompt is presented in Appendix 2, and the list of questions can be found in Table 3).

It could be argued that this step resembles the traditional questionnaire-based method for identifying students' interests. However, in this case students were requested to respond to student generated questions, not to adult's ideas. Furthermore, the list of reasons for interest used in step 2 was based on reasons given by students in step 1.

Sample

Step 1 *Probing questionnaire*. In order to collect self-generated questions in a formal setting, 373 questionnaires were distributed during the 2007/2008 school year in eight different high schools. All schools were attended by a culturally non-deprived secular Jewish population. All the participants were studying the same curriculum in Biology, since Israel has a centralized education system. It was assumed that the students' ability to read and write in Hebrew was similar for all schools. The schools and classes were selected based on teachers' initiatives and willingness to take part.

The first step in the data collection yielded a sample of 563 questions asked by 343 high school students: 30 respondents did not ask any questions, but others asked more than one question. The breakdown according to age, gender and elective courses is presented in Table 1.

Step 2 *Generalizing questionnaire*. In order to confirm the interest of the students in other students' questions collected in a formal setting, 375 questionnaires were collected

Table 1 Sample demographics for the probing questionnaires (step 1) and generalizing questionnaires (step 2)

	Biology majors		Non-Biology majors		Total
	male	female	male	female	
Probing					
10th grade	20	21	53	29	123
11th grade	7	22	58	48	135
12th grade	13	33	18	21	85
Total	40	76	129	98	343
Generalizing					
10th grade	29	38	57	30	145
11th grade	19	29	37	17	102
12th grade	26	21	45	27	119
Total	74	88	139	74	375

during the 2008/2009 school year from seven high schools with similar characteristics to those in step 1. Some of these schools were involved in the first step of the study as well; however, the same students did not take part in both stages. The breakdown according to age, gender and elective courses is presented in Table 1.

Students were cooperative in rating the questions and returned full questionnaires. Only 7% of the respondents did not answer why they found each question to be interesting.

Context

Almost 40% of the 718 participants were Biology majors. In Israel, at the end of ninth or tenth grade, students choose to major in at least one subject, which is later evaluated by a national matriculation examination. The curriculum for the Biology majors includes an obligatory inquiry project (90 teaching hours), obligatory inquiry lab experiments (90 teaching hours), and a selection from theoretical subjects (270 teaching hours). The theoretical subjects include three obligatory core topics which are studied at the 10th–11th grades (the cell, human biology, ecology), and two advanced elective topics which are studied at the 11th–12th grades (e.g. heredity, microbiology, reproduction, animal behavior, biotechnology) (Israeli Ministry of Education 2006). The choice of elective subjects is done by the teacher, guided by regulations which are subject to change. The students are usually examined by the end of 12th grade. The theoretical exam includes questions in all the elective topics, and students usually choose to answer questions in the topics they learned in class. Both Biology majors and non-majors were included in the sample in order to broaden our reach and determine whether students' questions related to their Biology studies.

Students were requested to ask questions on three specific topics which are generally taught in different grades: (1) genetic engineering (elective, usually taught in 12th grade); (2) the cardiovascular, coagulation and immune systems (obligatory at a basic level and taught at 10th grade, may be taught at an advanced level in 11–12th grade); (3) the reproductive system (elective, usually taught at 11–12th grade). The cardiovascular, coagulation and immune systems are included under the same heading in the official curriculum (henceforth simplified to "cardiovascular systems"). The questionnaire prompted students to ask about genetic engineering, and not genetics in general. However, students apparently did not make this distinction and asked many questions about other topics in genetics as well. The rationale for choosing these three subjects was to focus on three topics which are traditionally studied in different grades.

Analyzing Students' Questions

Students' questions were coded to reflect content, psychological distance from the asker, and links to the curriculum[2].

Question Topic: Subject and Sub-Subject Questions were coded in one of the following categories: genetics (Can genetic traits expire?), cardiovascular systems (Why do people say that Omega 3 from fish decreases the chances of having a heart attack?), reproductive system (Why does the black widow spider kill the male that fertilized her?), other Biology (What are the early signs, risks and ways of coping with diabetes?), other science (How does zero gravity affect the human body?). Classification was not always clear cut. A question such as "Can the duration of human embryonic development in the uterus be shortened without causing any damage?" could have been classified either as relating to embryonic development (reproduction) or to genetic manipulation (genetics). Our rule-of-thumb for such ambiguities was to find the question topic in the curriculum. Here, for instance, embryos are dealt with in the reproduction curriculum; thus this question was classified as "reproduction". When novel ideas which are not part of the curriculum were asked (Can a human and an animal have offspring together?) these questions were classified according to the topic in which such questions are usually raised in class.

Further classification of the genetics and cardiovascular questions into subcategories emerged during the analysis: questions were grouped based on similar themes and later given headings by the researchers. To ensure consistency, one of the authors performed all the coding. In order to establish inter-rater reliability, 15% of the 563 questions were coded independently by two coders, with 90.5% agreement.

Psychological Distance Questions were coded according to the psychological distance of the asker from the question topic, based on Bar-Anan et al. (2006). This method scores for spatial, temporal, social, and hypothetical (how likely is it for the target event to occur?) distance. The zero-anchoring point of all four dimensions is the perceiver's direct experience, where the stimuli are sensed in the here- and- now. Psychologically distal entities are objects and events that are not part of the perceiver's direct experience. We added another dimension to psychological distance; namely, scale. Objects which are too small or big to be experienced with our senses can be considered as psychologically distal (Baram-Tsabari and Yarden 2009c). Objects of interest were classified into three levels: 'myself' (If my parents have a tendency to get fat, will I also be fat?), 'direct environment' which the asker can observe and interact with (Are allergies inherited?), and 'distant environment' (Will someone find a cure for AIDS in the future?). To ensure consistency, one of the authors performed all the coding. In order to establish inter-rater reliability, 16% of the 563 questions were coded independently by two coders, with 91.1% agreement.

[2] Students' questions were also analyzed with regard to their cognitive level. Results are not presented since this study focused on the content of the questions.

Comparison of Alignment between Curriculum Weight and Students' Interest Bhola et al. (2003) described various methodologies to measure alignment between tests and States' content standards. The simplest method defines alignment solely with regard to content; a moderately complex method examines the dual perspective of content match and cognitive complexity. A high complexity model involves five interrelated dimensions: content match, depth match, emphasis, performance match, and accessibility.

The current study used the most basic definition, examining only content with regard to categorical concurrence to determine whether the concept/phenomenon/main idea appearing in students' questions also appeared in the curriculum. Since the Israeli national Biology curriculum does not quantitatively specify the requisite cognitive skills (e.g. critical thinking) (Israeli Ministry of Education 2006) cognitive alignment criteria could not be applied.

Agreement between coders Students' questions were mapped to the curriculum by one of the researchers, an experienced Biology teacher. It was checked for inter-rater reliability by six in-service high-school Biology teachers. All teachers read all 563 questions, and classified them as either addressed or not addressed by the relevant section in the curriculum, with 89% agreement.

Results

An Overview of Students' Interests in the Three Biology Topics

Self-reported interest According to their self-reports in the background information section of the questionnaire, the participants in the study were fairly interested in Biology (3.5 on a five point scale), and were very moderately interested in popular science (2.6 on a five point scale). All the subgroups of students —females and males, biologists and non-biologists, 10th, 11th and 12th graders— reported highest interest in genetics (3.6 on a five point scale), followed by reproduction (3.3), and the cardiovascular system (3).

On average, male students reported watching and reading popular science in their free time more than female students (2.78 and 2.42, respectively; $t=2.49$, $p<0.05$), as expected from the literature (Eurobarometer 2005; National Science Board 2008). Female students, on the other hand, reported a higher interest in Biology in general (3.6 and 3.3, respectively; $t=-2.31$, $p<0.05$), in agreement with findings worldwide (e.g. Baram-Tsabari et al. 2009b, c; Jenkins and Nelson 2005; Osborne and Collins 2001). Females were also more interested than males in topics related to the reproductive (3.45 and 3.04, respectively; $t=-2.991$, $p<0.01$) and cardiovascular systems (3.2 and 2.8, respectively; $t=-2.606$, $p<0.01$). As expected, Biology majors reported more interest in Biology than non-majors (4.5 and 2.9, respectively; $t=-12.204$, $p<0.01$).

Students' questions Genetics was the most popular subject for questions (43%), followed by the cardiovascular system (26%) and reproductive system (11%). One fifth of the questions referred to other topics in Biology or other sciences. Further classification of the genetics and cardiovascular questions into subcategories emerged during the analysis. The subcategories in order of popularity were: genetic engineering, heredity of physical traits and diseases, cancer, immunology, physiology of the heart, design babies, cloning, heart disease, other diseases, methodology of cloning, blood diseases, AIDS, blood types, mutations, DNA, heredity of character, smoking, allergies, drugs, blood tests, nature vs. nurture. No significant difference was found between genders or between majors and non-Biology majors with regard to question topics (gender: $t=-1.4$, $p=0.154$; elective subject: $t=1.611$ $p=0.108$).

However, further classification of the questions according to their sub-subject revealed that girls were more interested than boys in human health topics such as cancer, heart disease and heredity of physical attributes and diseases (Table 2). This mirrors trends found in the international ROSE project (Busch 2005; Jenkins and Nelson 2005; Schreiner 2006) and an analysis of students' questions (Baram-Tsabari and Yarden 2009c). Male students were more likely than females to ask about molecular genetics methodologies such as genetic engineering and cloning products (Table 2).

Biology majors were far more likely than non-Biology majors to raise questions about the distant environment, which cannot be directly experienced by the senses (57.5% and 35.4%, respectively, $t=5.164$, $p<0.01$). Biology non-majors were relatively more likely than biology majors to ask questions concerning themselves (11.1% and 2.6%, respectively) or their direct environment (47.9% and 41.2%, respectively; $t=56.164$, $p<0.01$).

Validating the Generality of the Results

A sample of the students' questions collected in the probing stage was presented to another sample of 375 students, in order to confirm their appeal to others than those who originally raised them.

The great majority of the questions (29 out of 36) were ranked as interesting by the participants (average score of over three out of five, Table 3). Only seven questions received neutral or slightly negative average scores (2.55–3). This finding indicates that overall, the questions raised by the students in the probing phase were potentially interesting to a wider student body. Moreover, only two questions received neutral or slightly negative average scores among Biology majors (Table 3). This finding indicates that the questions raised by the students in the probing phase were potentially interesting to Biology majors. The aim of this stage was to validate the generality of the interests identified in the first stage of the study. However, the generalizing questionnaire yielded additional findings regarding students' interest in Biology.

As in the probing phase, genetics was clearly the most interesting topic, scoring nine out of the ten most interesting questions (Table 3). Questions concerning the reproductive

Table 2 A comparison of themes found in female and male students' self generated questions

		Females ($n=174$)[1]	Males ($n=169$)
Human health	Cancer	5.3%	3.8%
	Heart disease	4.3%	1.5%
	Heredity of physical traits and diseases	10.6%	7.7%
Molecular genetics methodologies	Genetic engineering	7.7%	12.7%
	Cloning products	1.7%	5.4%

[1] Some students asked more than one question. The percentage is calculated of the total number of questions asked by students from each gender.

Table 3 Generalization questionnaire results. Students' questions ordered by their overall average score on a 1–5 Likert scale. For the subgroups of male, female, biology and biology non-major students, the popularity of each question is indicated on a scale from 1 to 36, followed by the average score

	Question (topic)[1]	All sample (n=375)	Male (n=213)	Female (n=162)	BM[2] (n=162)	Non-BM (n=213)
1	How does cancer develop and how can it be treated? (g)	4.17	2 (3.96)	1 (4.44)	2 (4.23)	1 (4.12)
2	Can humans be cloned and how could it be done? (g)	4.05	1 (3.98)	6 (4.12)	1 (4.28)	4 (3.86)
3	Will we be able to create humans with perfect health in the future? (g)	4.03	3 (3.94)	5 (4.15)	3 (4.18)	3 (9.20)
4	How can a heart attack be prevented? (c)	4.03	4 (3.90)	2 (4.20)	6 (4.04)	2 (4.02)
5	How can a DNA sample identify a person? (g)	3.97	5 (3.80)	4 (4.18)	5 (4.15)	5 (3.82)
6	Is it possible to know, in advance, which traits pass from parents to their offspring and prevent them from being passed, or change those traits? (g)	3.91	9 (3.69)	2 (4.20)	4 (4.16)	6 (3.71)
7	What can be done with genetic engineering today? (g)	3.83	5 (3.88)	15 (3.74)	6 (4.04)	8 (3.66)
8	In the future, will we be able to choose how our baby will look? (g)	3.82	10 (3.61)	7 (4.11)	8 (4.02)	8 (3.66)
9	Can organs for transplant be created using genetic engineering? (g)	3.77	8 (3.70)	12 (3.83)	9 (3.96)	10 (3.61)
10	If my grandfather had cardiac arrest, does that increase the chances that I will have one too? (g)	3.75	11 (3.59)	9 (3.96)	10 (3.86)	7 (3.67)
11	What happens if human semen inseminates the ovum of another animal? (r)	3.64	14 (3.44)	11 (3.90)	11 (3.82)	12 (3.51)
12	What is a mutation and what causes it? (g)	3.6	12 (3.58)	18 (3.60)	15 (3.69)	11 (3.52)
13	Are personality characteristics genetic? (g)	3.59	17 (3.34)	10 (3.93)	12 (3.79)	14 (3.44)
14	Is the immune system influenced by psychological factors, and to what extent? (c)	3.58	15 (3.41)	3 (3.82)	13 (3.75)	13 (3.46)
15	Can I know, in advance, if I am sterile? (r)	3.54	19 (3.15)	8 (4.04)	15 (3.69)	16 (3.42)
16	Is athletic ability hereditary? (g)	3.49	13 (3.46)	19 (3.54)	18 (3.56)	14 (3.44)
17	Does my blood type say anything about me? (c)	3.49	18 (3.26)	14 (3.77)	14 (3.70)	17 (3.31)
18	Are sexual preferences hereditary? (g)	3.34	22 (3.04)	16 (3.73)	17 (3.59)	21 (3.15)
19	What is the difference between a carrier and an AIDS patient? (c)	3.30	22 (3.04)	17 (3.62)	22 (3.41)	18 (3.21)
20	Which has more influence—nature or nurture? (g)	3.26	20 (3.09)	20 (3.48)	19 (3.44)	22 (3.13)
21	If I inject myself with more red blood cells, will I be able to run faster? (c)	3.26	16 (3.36)	34 (3.12)	25 (3.32)	18 (3.21)

Table 3 (continued)

	Question (topic)[1]	All sample (n=375)	Male (n=213)	Female (n=162)	BM[2] (n=162)	Non-BM (n=213)
22	Are body type and height hereditary? (g)	3.25	20 (3.09)	21 (3.46)	21 (3.43)	23 (3.12)
23	How do you treat a person whose blood does not clot? (c)	3.21	22 (3.04)	23 (3.44)	23 (3.40)	24 (3.08)
24	How does the body handle allergies? (c)	3.17	28 (2.93)	21 (3.46)	24 (3.34)	25 (3.02)
25	What is high/low blood pressure? (c)	3.15	26 (2.97)	26 (3.37)	32 (3.06)	18 (3.21)
26	How does vaccination work, and how can you make someone immune to a disease? (c)	3.13	27 (2.94)	26 (3.37)	19 (3.44)	27 (2.89)
27	Are all male penises suitable for all female vaginas? (r)	3.13	25 (3.01)	29 (3.27)	28 (3.20)	26 (3.01)
28	Is there a difference in the number of genes that the offspring receives from the mother and father? (g)	3.05	7 (3.77)	25 (3.40)	26 (3.30)	29 (2.86)
29	When does life start—when the ovum and sperm meet or when the baby is born? (r)	3.01	35 (2.73)	28 (3.35)	30 (3.16)	28 (2.88)
30	How do you clean a blood vessel that is blocked by fat? (c)	2.99	31 (2.83)	31 (3.19)	28 (3.20)	31 (2.83)
31	Why is smoking unhealthy? (c)	2.98	29 (2.92)	36 (3.04)	27 (3.23)	32 (2.79)
32	How do sound and smell influence the courting process? (r)	2.94	30 (2.84)	35 (3.07)	33 (3.05)	29 (2.86)
33	How are infertility treatments done? (r)	2.83	33 (2.37)	24 (3.43)	31 (3.09)	33 (2.62)
34	What is IVF? (r)	2.73	34 (2.36)	30 (3.22)	34 (3.03)	35 (2.50)
35	If a woman does not give birth, can she still produce milk and breastfeed? (r)	2.72	32 (2.38)	32 (3.15)	35 (2.92)	34 (2.55)
36	Can a woman's stock of ovum run out? (r)	2.55	36 (2.09)	33 (3.14)	36 (2.76)	36 (2.39)

1 Classification according to the three biological topics: *g* genetics, *c* cardiovascular, coagulation and immune systems; *r* reproductive system

2 *BM* biology majors. *Non-BM* non biology majors

system, on the other hand, were the least interesting to the students, with five out of the five lowest ranking questions, slightly below the neutral point on the Likert-scale (Table 3).

Female students ranked almost all of the questions as more interesting than male students did, reinforcing their higher self-reported interest in Biology. Only three questions received higher averages from male rather than from female students (questions 7, 21, 28, on Table 3). Examining only male students' rankings (n=213, Table 3), revealed the questions that were relatively more interesting to them than to females. These included questions regarding genetic manipulation (e.g. questions 2 and 9, Table 3), and sports (e.g. question 16, Table 3).

Female students (n=162) were much more interested than their male peers in reproduction and specifically in infertility treatment. The widest gap between female and male rankings was found for questions referring to infertility (15, 33, 34, and 36, Table 3). Other gender-specific questions had to do with breastfeeding (question 35, Table 3) and character (questions 13 and 18, Table 3).

Biology majors ranked 35 out of 36 questions as more interesting than non-majors did, reinforcing their higher self-report of interest in Biology. Only one question was rated higher by non-majors, asking for an explanation of the terms high and low blood pressure (question 25, Table 3). Presumably, Biology majors were not as interested, since many of them already knew the answer, which is discussed in the curriculum.

Examining only Biology majors' rankings (n=162, Table 3), revealed that only two questions received neutral or slightly negative average scores. The questions that interested Biology majors more than non-Biology majors mainly concerned genetic manipulation (e.g. questions 2 and 6, Table 3). Biology majors were relatively uninterested in basic factual questions (e.g. questions 12 and 19, Table 3). Examining only non-Biology majors' rankings (n=213, Table 3) showed their high interest in personal and family health (e.g. questions 4 and 10, Table 3).

Comparison of Alignment between Curriculum Emphasis and Students' Interest

Mapping the level of congruence between students' interests, as reflected by the questions they raise, and the national curriculum revealed that half (n=284) of the questions asked by the students on the topics of genetics, cardiovascular and reproductive systems are not addressed by the curriculum. Over 15% of students' questions which were not answered by the curriculum were concerned with reproduction. Other fields which were the focus of many unanswered questions were genetic engineering (10.5%), heredity of physical traits and diseases (7.5%), cancer (4.5%), designer babies (4.5%), and cloning (2.5%).

Biology major's questions were more likely to be left out of the curriculum than questions asked by non-biologists (55.6% and 45%, respectively). This may indicate that the Biology curriculum in fact does address some of the spontaneous interests of students. Therefore, students who did not study Biology raised more questions which are answered by the Biology curriculum.

The different types of interactions between students' interests and the formal curriculum, and the incorporation of these interests into an annotated shadow curriculum, are analyzed and discussed in the following section.

Discussion

High school students' interests in three biological topics were identified based on their questions. Presenting a sample of frequently asked questions to another group of high school students verified they were indeed interesting to other students as well. The comparison of themes emerging from students' questions with the content dictated by the curriculum revealed a partial mismatch between students' biological interests and the formal curriculum: half of the questions raised by the students were not addressed by the curriculum. The percentage of unanswered questions was even higher for Biology majors.

The discrepancy between students' interests and the national curriculum is consistent with the Wood et al. (2009) claim that existing educational policy, and the research on which it is based, does not adequately consider student culture. As a result, cultural mismatches between students' worlds and classroom practices are barriers to learning and achievement. Many factors, such as the nature of instruction and assessment, to name only two, affect students' learning and achievement in school Biology. This study views students' interests as yet another important and rather neglected factor, and therefore emphasized student input into teaching and curriculum design.

Interactions between Students' Interests and the Formal Curriculum

A comparison of alignment between the curriculum and students' questions revealed three patterns of interaction. Students' questions may (1) complement and build on the existing principles in the curriculum; (2) emphasize specific contexts of existing principles in the curriculum, while ignoring others, and (3) refer to different principles, which are absent altogether from the curriculum.

(1) *Complementing existing principles.* The genetics curriculum, for example, addresses the idea that the observable characteristics of an organism (phenotype) are the result of its inheritance (genotype) and environmental effects. It does not, however, address the balance between genetic and environmental factors. This balance was a prevalent theme in students' questions, such as (translation of verbatim quotes): "What is more influential the environment, education or genetics?"; "Can genetics affect the level to which my body is able to develop (body building)?"; "If my parents have a tendency to be fat, will I be fat too?"; "Are hobbies and topics of interest hereditary?". Recent research in genetics can provide some answers to these questions (Clark and Grunstein 2000), but the curriculum does not respond to students' interests in any of these areas.

Another example is the case of cancer. Cancer is addressed in the Israeli Biology curriculum only once, as an example of uncontrolled cell division within the genetics curriculum. Cancer is one of the most common diseases in the world, and most of the students had encountered the disease when it affected relatives or family friends. Students raised a variety of questions about cancer: they wanted to know what it is, what damage it causes, similarities and differences between types of cancer, whether it is infectious, whether there are genetic factors, how a treatment can affect fertility, how it can be identified and prevented, etc. The life sciences can at least partially answer many of these questions (Weinberg 2007), but the curriculum does not respond to students' interests in this area.

The same notion of students' interests as complementing the curriculum was found with regard to the cardiovascular system. An existing section in the curriculum addressing the cardiovascular system presents the general idea that blood is a unique tissue, made of salt, cells and cell parts which are in constant motion, and that blood tests are a key to diagnosis. Students were much more specific and practical in their questions (verbatim quotes): "How do you check the iron level in the blood as opposed to iron stored in the body?"; "How can I understand blood test results?", and related science to their personal and social lives, as in "What does my blood type say about me?" and "Why do some people have darker blood than others?". Students were very interested in the possible connection between the difference between blood types and weight, personality traits, nutrition, skin color, the structure of the cells and their ability to clot. Again, the curriculum does not respond to students' interests in any of these areas.

(2) *Emphasizing specific contexts of existing principles*. The genetics curriculum provides an example of this kind of interaction concerning the application of genetic

engineering to agriculture, biotechnology industry and medicine. Five examples are listed in the curriculum—three in the context of agriculture, two in the context of the biotechnology industry and one in the context of medicine. Students' questions, on the other hand, ignored applications in agriculture, asked few questions about the biotechnology industry, and addressed the medical applications of genetic engineering.

These findings mirror those described by Kidman (2009), in which Australian students were most interested in biotechnology topics that might have personal relevance or ideas that involve hands-on experimentation, whereas their teachers were most interested in teaching about GM crops.

(3) *Addressing principles that are not found in the curriculum*. Some students' questions in the field of reproduction addressed principles which are totally absent from that section of the curriculum. Students, and especially girls, were interested in things that can go wrong in the reproductive system —dysfunctions, diseases, abnormalities, infertility and ways to treat them. "Does gender affect ways of thinking and intelligence?" refers to yet another neglected idea— the possible connection between gender and different abilities. The reproduction curriculum does not address interspecies fertilization at all, but students find this idea fascinating, especially regarding mammals, asking "What would happen if a chimpanzee's sperm fertilized a human egg?".

The field of genetics is a telling example of the mismatch between students' appetite for knowledge and the formal diet provided by our schools. Genetics was the most popular subject according to students' self-reports, the number of questions raised in the probing phase, and the ranking in the generalization phase (in which nine out of the ten most popular questions referred to genetics). Biology majors were especially interested in genetic manipulation techniques, such as cloning and genetic engineering, and their implications for human medicine and reproduction. The disparity as regards students' interest was found at three levels:

(1) *Within the genetics curriculum*. A mismatch was found between students' interest in human implications of biotechnology and the emphasis of the curriculum on agriculture.
(2) *Within the Biology curriculum*. The new curriculum that was introduced in 2006 has minimized the recommended teaching time allocated for genetics compared to the older version.
(3) *Enacted curriculum.* Genetics is only one of the elective advanced units a teacher can choose for Biology major classes. Therefore, only a minority of dedicated teachers actually choose to teach advanced genetics in our school system, for practical reasons (Agrest 2001): in 2005 and 2006 only 23% of all Biology majors picked the questions about genetics on the matriculation exam. In 2007 this percentage dropped to 13%[3] (Mendelovici 2009).

In all these aspects, the school system fails to respond or build on the genuine interest of so many students in genetics.

[3] It is possible that some students studied genetics but chose not to answer the genetics question on the exam if their teachers taught them an extra elective subject. Direct data as to the number of teachers who taught advanced genetics as an elective subject in recent years are unavailable.

Implications

Using Students' Questions to Inform Teaching: Creating a Shadow Curriculum

Students' questions may serve as an updating tool to better link the curriculum to their interests and informational needs. However, classroom implementation may be problematic. Let us consider the topic of 'cancer'. Since it is not a prominent part of the curriculum, when (and if) students ask about it spontaneously in class, they often interrupt the teacher who has a different lesson plan in mind. The teacher might also not have all the information to answer correctly without doing some research. Even if the teacher happens to have an answer ready for each question, Rop (2002) found that teachers are ambivalent even to students' questions that stem from curiosity and involvement in the subject matter. Although thoughtful intellectual questions are valued, they nonetheless create an interruption in the normal flow of things, and pose threats to the teachers' control of classroom events and his or her ability to cover the content of the course.

This suggests that the identification and incorporation of students' interests into the lesson should be at least partially preplanned, and not completely left to the spontaneous enactment of the lesson. It is important to note, however, that even if we had a clear-cut understanding of what students really want to know, and the use of student-interest focused learning materials demonstrating pedagogical benefits, the science curriculum would still not rely solely on students' interests for educational and practical reasons. Some students' interests may not be aligned with the intended outcomes of the curriculum, such as the development of science literacy or science proficiency. Therefore, this was not an attempt to design a curriculum from the ground up based on students' interests. Students' interests are identified and used with regard to the existing curriculum, and not as an independent yardstick for science teaching.

In order to create an annotated curriculum which reflects the interests and informational needs of the students, their questions had to be translated into the curricular language of principles, phenomena and concepts. Table 4 presents the overlaps and missing themes in the context of two main ideas in the genetics curriculum.

Questions addressing the balance between genetic and environmental factors in determining different traits were reformulated in the shadow curriculum by the statement "each trait is determined by a different balance between genetic and environmental factors", and specific examples were listed under "concepts and contexts" (Table 4, upper row). The students' questions were more concrete and specific than the ideas and concepts in the curriculum, and therefore could be used as examples for the required content. Naturally, not all the examples could or should be addressed in every classroom. However, they may direct the teacher to an engaging context for teaching since the interest of other students rather than the ones raising the questions has been demonstrated. Israeli teachers and textbooks, for example, tend to use height as an archetype example for a trait which is affected both by the genetic makeup and environmental conditions (primary nutrition in this case). The list of questions revealed many other examples that might engage students more.

Students' emphasis on genetic manipulation in humans was also striking (Table 4, second row): biotechnology in agriculture was not a subject of questions, whereas biotechnology in medicine was. Thus interesting phenomena were added to the shadow curriculum based on students' questions with the aim of providing a more engaging context for teaching the same principle.

Two novel ideas were added to the reproduction curriculum to address students' interest in dysfunctions, diseases, abnormalities, infertility and ways to treat them (Table 5, middle row) and the possible connection between gender and different abilities (Table 5, last row).

Table 4 A Shadow curriculum**.** A short excerpt from an annotated curriculum in genetics

Principles	Phenomena	Concepts and contexts
The phenotype of each organism is a result of its genotype and an environmental influence in which it develops and exists.	Hereditary features and acquired attributes; environmental influence on hereditary features. *Each trait is determined by a different balance between genetic and environmental factors.*	Identical twins, fraternal twins. *Hereditary heart diseases, immune system, intelligence and knowledge, sexual orientation, body shape, talent, metabolic rate, cancer, alcoholism, body structure, life expectancy, personality traits (shyness), abnormalities, achievements, hobbies, areas of interest.*
Our knowledge of inheritance and genetic engineering is being used in agriculture, biotechnology industry and medicine.	Examples of applications: increasing plant resistance, and crop yields, manufacturing proteins and hormones, genetic therapy, cloning (cells and organisms), *Enhancing human abilities (sight, hearing* etc.*), human cloning, short life-span of cloning products, tissue engineering.*	

Plain font—Topics in the formal curriculum that are not mentioned by students' questions (verbatim translation of the syllabus); *Italic—Topics mentioned in students' questions but are not included in the formal curriculum* (students' questions translated into curricular terms and then into English); Underlined—Topics mentioned in students' questions and included in the formal curriculum (verbatim translation of the syllabus). In the original curriculum the heading is "concepts". In the shadow curriculum we added "contexts", to include students' interests and associations which are not strictly biological concepts, such as "shyness".

We would like to suggest the following steps as a procedure that could be used by other researchers and practitioners to guide the development of a curriculum that is more aligned with students' interests:

1. *Identify*. Identify students' interests and information needs on a certain topic. This could be achieved by using the existing literature, the archives of Ask-A-Scientist sites (e.g. *MadSci Networks* www.madsci.org), or anonymous questionnaires to target students, asking them to raise questions they would like to learn about related to that topic.
2. *Generalize*. If students' questions are used in a different context from the one in which they were raised, the generality of these questions should be first evaluated. For example, before using Turkish students' biology questions to create an interesting Israeli biology curriculum, a survey should be conducted, asking students to rate their level of interest on a sample of questions.
3. *Compare*. Assess the alignment between curriculum emphasis and students' interests. Identify the different interactions: when do students' interests match, or emphasize certain parts of the curriculum? When do they fail to overlap?
4. *Create*. Creating a shadow curriculum involves two steps:

    a. Mapping each question to the most relevant principle or concept in the curriculum.
    b. Distilling the question into the curricular language of principles, phenomena and concepts. The context of each question should also be noted to choose engaging examples.

Table 5 A Shadow curriculum. A short excerpt from an annotated curriculum concerning the reproductive system

Principles	Phenomena	Concepts and contexts
The zygote develops into a mature organism via cell division, growth and differentiation.	Development of human embryo (representative example): embryonic environment: feeding, secreting, embryonic membranes. Pregnancy and birth.	Mammary glands, placenta, corpus luteum, laying, spawning, giving birth, zygote, follicle, yolk, animals without placenta, amniotic fluid, progesterone, Prolactin, muscle contractions, birth, uterus, mucous membrane, yolk sack, amniotic sac, *twins, elephants' pregnancy, vacuum assisted birth.*
The length of embryonic development differs between organisms.	*Stages of embryonic development. Development of twins. The maternal protection of the embryo in the uterus is not absolute.*	
Embryonic development occurs within a protective mucous.	Embryonic development in an egg, egg structure (Aves). *Similarities and differences between embryonic development in eggs, spawning and in the uterus.*	
Abnormalities, dysfunctions, and sexually transmitted diseases sometimes occur in the reproductive system.	*Intercourse does not create diseases in healthy partners. The genitals are not always perfect. Length of a penis is not necessarily an advantage or disadvantage in sex and reproduction. Various infertility treatments exist. Some people are born with sex organs of both sexes.*	*Condom, common sexually transmitted diseases (AIDS), preventing sexually transmitted diseases, sterility, androgyny.*
Connection between gender and various abilities.	*Gender, thinking strategies and intelligence.*	

Plain font—Topics in the formal curriculum that are not mentioned by students' questions (verbatim translation of the syllabus); *Italic—Topics mentioned in students' questions but are not included in the formal curriculum* (student's questions translated into curricular terms and then into English); Underlined—Topics mentioned in students' questions and included in the formal curriculum (verbatim translation of the syllabus). In the original curriculum the heading is "concepts". In the shadow curriculum we added "contexts", to include student's interests and associations which are not strictly biological concepts, such as "condom".

Problematizing the Role of Students' Interest

Mcphail et al. (2000) suggested that coming to understand students' learning interests and using them in the design of curricula can foster their identities as competent learners. However, the notion of incorporating students' interests into science teaching is far from being methodologically and practically straightforward. Here we highlight a few of the obstacles that might hinder the process, alongside open questions for consideration.

(1) Identifying students' interests. Are students' questions a reliable source of their own interests across time and situations? Which other student-centered measures can be used, especially for topics that require a great deal of prior knowledge? Would simply asking students what are they interested to know about a specific topic yield similar, or even more useful, results? How can fleeting curiosity be distinguished from a stronger interest that might foster learning for longer?

(2) The generality of students' interests. Students' interest may depend on various environmental, regional, cultural, social, national, religious and other factors. Although some similarities have been pointed out (e.g. Cakmakci et al. 2009), it is not at all clear how generalizable are students' interests. This raises the question—how

much can students' interests be assumed to be similar across time, cultures, countries, age groups and genders? Should each teacher conduct a probing phase prior to teaching or could there be an updated national/local shadow curriculum on a common wiki page?

(3) Comparing the emphasis of the curriculum and students' interests. To what extent does content analysis performed by a science educator reflect the true intentions of the students' questions?

(4) Incorporating students' interests into the formal Biology curriculum. Will students' questions still be interesting when they become part of a formal lesson?

Conclusion: From Popularization of Science to Scientification of Students' Interests

One of the eleven emerging issues raised in a recent UNESCO report was the role of interest in and about science. "Policy makers should make the issue of personal and societal interest about science the reference point from which curriculum decisions about learning in science and technology education are made about content, pedagogy, and assessment". Further, it states, "In the secondary years the role of S&T in the students' worlds outside of school should play a powerful motivating role" (Fensham 2008 p. 6). In order to achieve this goal, the traditional process of popularizing scientific research into digestible learning materials should be reversed by using students' input as raw material for a "scientification" process; i.e., providing a scientific basis for learner's authentic concerns and interests.

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Appendix 1: Probing Questionnaire

Dear Participant,

I believe that if the content in biology studies interested you, you would learn, remember and enjoy more. Therefore I would be grateful if you could take a few minutes to answer this questionnaire. It will help me match the Biology curriculum to students' interests. I have chosen to focus on three subjects in Biology that are taught in tenth, eleventh, and twelfth grade: the intravascular system (cardiovascular, coagulation and immune systems), the reproductive system, and genetic engineering. Thank you for participating.

A. Background information

Gender: M/F Grade: 10th 11th 12th

My elective fields for the matriculation exams are: ______________________

	Not at all				Totally agree
I am interested in topics related to Biology	1	2	3	4	5
I am interested in topics related to the intravascular system (blood, heart, immunization, and clotting)	1	2	3	4	5
I am interested in topics related to the reproductive system	1	2	3	4	5
I am interested in topics related to genetic engineering	1	2	3	4	5
In my free time, I sometimes read or watch popular science	1	2	3	4	5

B. Questions that interest me

In the space provided below, please write questions you would like to know the answer to, that are related to the intravascular system (blood, heart, immunization, and clotting), reproduction or genetic engineering. The questions can relate to everyday life, and do not necessarily need to be something you learn in school. I would appreciate it if you could explain why the questions interest you (personal reason, personal health, family health, something I read, something I learned, rumors, curiosity, faith, etc.)

My question Why is it interesting to me?

(more space was left in the original questionnaire)

Appendix 2: Generalizing Questionnaire

[Sections A (background information) and C (Questions that interest me) are identical to sections A and B in the probing questionnaire, and are not repeated here.]

B. The following questions were asked by high school students. For each question, please mark the extent to which you would be interested in getting an answer to that question in Biology class (1—not interested, 5—very interested). Write the number that best describes the reason for your interest or lack of interest. (1) Personal health (2) Family health (3) Curiosity (4) Something seen or heard (5) Important to my future (6) Something I learned (7) Already know the answer (8) The topic doesn't interest me. You may also add a reason that is not listed.

[36 questions were presented in a table with a five point Likert-scale. The questions in order of popularity can be found in Table 3]

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