Chapter 2
Enhancing the Authenticity of a Web-Based Module for Teaching Simple Inheritance

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Introduction

In this chapter, we view socio-scientific issues (SSI) as contributing to dialogic argumentation (Ash & Wells, 2006; Driver, Newton, & Osborne, 2000; Tal & Kedmi, 2006) and as enhancing the ability to assess scientific information and data (Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Zohar & Nemet, 2002), which both contribute to scientific literacy of students in middle and lower high school grades (Roth & Calabrese Barton, 2004). Teaching science through socioscientific issues is in line with ideas brought up by the Science-Technology-Society (STS) movement (Aikenhead, 1994; Hodson, 1994, 1998) that continued to develop into ideas about humanistic science teaching and teaching citizen science (Aikenhead, 2005; Calabrese Barton, 2003; Roth & Calabrese Barton, 2004; Tal & Kedmi, 2006). The essence of all these ideas is that the science content should be situated in real, important, and often controversial issues that gain the public's interest. Ratcliffe and Grace (2003) identified the following characteristics in socioscientific issues: they have a basis in science as they are frequently at the frontiers of scientific knowledge; they involve forming opinions, making choices at personal and societal levels; they are frequently reported by media; they deal with incomplete information; they address local, national, and global dimensions; they involve some cost-benefit analysis in which risk interacts with values; they may involve considerations of sustainable development; they involve values and ethical reasoning; they may require some understanding of probability and risk; they are frequently topical with transient life (pp. 2–3).

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Integrating societal, environmental, and technological aspects into the science curriculum is not a new idea. The Science-Technology-Society (STS) movement of the 1980s advocated not only the inclusion of controversial issues, but using them as organizers for the curriculum (Bingle & Gaskell, 1994; Solomon & Thomas, 1999). However, as Zeidler and his colleagues argue (Zeidler, Sadler, Simmons, & Howes, 2005), in fact, socioscientific issues were presented merely as additions or anchoring stories to the main stream science that remained disciplinary, standard-based, and free of value. They suggested that the Socioscientific Issue (SSI) movement should replace STS, claiming that while STS education typically stresses the impact of decisions in science and technology on society, it avoids deep engagement with ethical issues and does not consider the moral development of students. With this regard, Tal and Kedmi (2006) argued that this criticism is more about the employment of STS than about its core ideas. Scholars who advocate for a more central role that socio-science should play in science teaching believe that issues such as genetically modified food, nuclear energy and nuclear waste, stem cells research, gene therapy, biodiversity, and so forth that enhance public discourse through the mass media should become the context of science teaching for the future citizens. In an attempt to locate socioscientific issues in the curriculum, Ratcliffe and Grace (2003) point to citizenship, scientific literacy and sustainable development as dealing with values, conceptual understanding and skills. They identify the connections between STS goals and environmental education in contributing to scientific literacy, citizenship, and sustainable development, and argue that despite the different foci, "attention to procedural understanding of reasoning and decision making, combined with acknowledgement and elaboration of values is a feature of all three" (p. 35). Ratcliffe and Grace suggest that socioscientific issues can be a means to achieve the ambitious goal of students acting as informed, responsible citizens when confronted with future scientific advancements. Within the large scope of SSI, in this chapter, more emphasis is given to conceptual understanding and citizenship.

With respect to teaching methods, it is widely agreed among STS/SSI/EfS/EE[1] proponents that teaching should be a process of negotiation and inquiry and that elements of authentic involvement of the students in decision-making and action should be included as well (Hodson, 1994; Sadler, Barab, & Scott, 2007; Sadler & Zeidler, 2004). Decision-making is a major element of being a citizen in a democratic society and the way to support youth in making informed decisions is considered as citizenship education and education for sustainable development. Citizens of the twenty-first century need to take a stand in environmental, health, economical, social justice, and many other issues, but the traditional teaching in most schools does not support students in becoming active citizens (Hodson, 2002). As Hodson argues, teachers struggle when they try to present science as a value-laden activity because the topics they teach are usually neutral. Socioscientific issues which are heavily loaded with values are much more appropriate to convey this message.

[1] STS – Science-Technology-Society; SSI – socioscientific issues; EfS – education for sustainability; EE – environmental education.

From International to Local Context

In Israel, since the 1990s, STS has become the framework of science education in the elementary and the junior high school levels. However, in line with Hodson (2002) and Zeidler et al. (2005), the societal and environmental issues remained as enrichment or merely decoration to the core science content. The only place in which socioscientific issues became a legitimate organizer of the entire curriculum was in the "Science and Technology in Society" (STiS) curriculum (MUTAV – in Hebrew), a curriculum for nonscience majors in the high school, which is studied by small number of students, usually in lower academic tracks. Within the context of STiS, various modules were developed around socioscientific issues. In these modules, the designers aimed at developing the students' questioning skill (Dori & Herscovitz, 1999), their argumentation (Dori, Tal, & Tsaushu, 2003; Tal & Kedmi, 2006) and decision- making, through learning about genetic engineering, air quality, ocean wildlife conservation, and so forth. In doing so, the designers of the modules addressed the four levels of sophistication suggested by Hodson (1994) which, in short, are (1) appreciating the societal impact of scientific and technological change; (2) recognizing that decisions about scientific and technological development are taken in pursuit of interests; (3) developing one's own views; and (4) preparing for and taking action. In the junior high school level, despite the flexible framework of the curriculum, and substantial attempts to develop knowledge integration or higher order thinking skills such as system thinking (Ben-Zvi Assaraf & Orion, 2005; Kali, Orion, & Eylon, 2003), or exposing the students to advanced research technologies to improve conceptual understanding (Margel, Eylon, & Schetz, 2004), only few attempts were made to promote thinking by using socioscientific issues for supporting higher order thinking in science and environmental education (Dori & Tal, 2000; Tal & Hochberg, 2003; Zohar, 2004; Zohar & Nemet, 2002).

Curriculum and Context

The use of socioscientific issues for enhancing students' science literacy will be presented here in the context of technology-enhanced learning in small groups using a Web-based module named Simple Inheritance, developed in WISE. The Web-based Inquiry Science Environment (WISE) was designed to enhance science learning, while taking advantage of the innovations that the Internet can bring into the teaching and learning of science. The WISE library includes several dozen modules, most of which are approximately 2 weeks in length and designed by teams of researchers and teachers, in various fields of science for upper elementary, middle, and high school students (Slotta & Linn, 2009). Many of these modules introduce science contents within health, environmental, and social contexts. For instance, in the asthma module, students investigate how asthma affects the human body, and how it is affected by environmental factors such as pollution (Tate, 2008; Tate, Clark, Gallagher, & McLaughlin, 2008). In the global warming module, students explore the causes for global warming using an interactive visualization which models the various factors involved (Varma, Husic, & Linn, 2008). While learning with WISE modules, students learn scientific content in relevant contexts, and develop a variety of thinking skills such as asking questions, identifying and critiquing evidence, making arguments, making hypotheses, and so forth. Interactive visualizations in WISE modules allow the students to explore complex phenomena and processes and integrate knowledge from various resources (Linn, Lee, Tinker, Husic, & Chiu, 2006). In WISE, students can work individually, as well as in small groups. For teachers, WISE allows modifications, additions, and on-going revisions to improve learning (Slotta & Linn, 2009).

The work reported here takes advantage of another capability of WISE – the authoring environment, which allows one to revise, adapt, and refine existing modules. In discussions involving the WISE research team and our research group, the WISE researchers expressed some concerns that had emerged with the Simple Inheritance module. They felt, and we concurred that this particular module needed some targeted revisions in order for it to support the desired learning outcomes. The WISE Simple Inheritance module along with associated test questions and coding rubrics were developed by Benemann (2005) with the support of the Technology Enhanced Learning in Science (TELS) research group. The module begins and ends with a framework story of Eric, a boy who is sick with cystic fibrosis (CF), a disease that affects his ability to hike with his family. The students explore Eric's family history to arrive at the conclusion that CF is an inherited trait. This context allows for further investigation of other inherited traits and learning about simple genetic mechanisms. Despite the engaging context and the anchoring story, of a sick child that launches the learning sequence, we believed that a "real life" context could make a greater contribution to students' learning. We assumed that other opportunities for social interactions to advance learning will further contribute to the students' engagement and learning (Ash, 2002, 2004; Ash & Wells, 2006).

Our endeavor is based on a previous study in which Tal and Hochberg (2003) employed the WISE Malaria project and attempted to strengthen the argumentative dialog in the classroom. Tal and Hochberg added two socioscientific issues to the basic module – one that dealt with the dilemma of eradication of the small pox virus, and the other dealt with a debate about vaccination against the West Nile fever virus. These socioscientific issues were used to support learning as well as assessment goals. For both issues, a whole-class discussion followed web-based learning exercises. In addition, Tal and Hochberg incorporated a sociocultural dimension to the learning process. Three classes, one of students from a middle-high socioeconomic suburban community, another of students from an urban school of mainly immigrants from the former Soviet Union, and the third class of Arab students, all who learned the malaria module at the same time, met for a "socioscientific conference" in which the students presented posters of their learning outcomes about malaria and participated in mixed groups to discuss the societal issues that affect science, health, and the environment. Tal and Hochberg, who employed the assessment scheme suggested by Zohar and Nemet, found that in the West Nile fever issue, which was given at the end of the module, the students' performances in tasks that required complex reasoning were significantly higher than their performance in the small pox virus preproject assignment. They also found that the students addressed more perspectives on the issue and that they better addressed scientific knowledge in supporting their justifications. Following the same line of thought, we believed that enhancing the authenticity of the Simple Inheritance module by adding a meaningful social interaction to the learning process will contribute to students' learning. We postulated that the contribution will be in both the affective and the cognitive domain.

In addition to better contextualizing the module to the Israeli context, we added two components to the original module: The first component, experienced by one class, was a visit to a CF unit in a children's hospital, and the other component was authentic communication through an asynchronous forum (online interaction). This forum allowed students to talk with a young CF patient over a period of a few days. Generally, we were interested in patterns of learning with the adapted WISE module, and more specifically, we were interested in the value of the two additions that aimed at improving the relevance of the module. Our research team consisted of an expert in technology-enhanced learning, an expert in teaching socioscientific issues who studies learning in informal settings, and an experienced science teacher in grades 8–10 (age 14–16). In this chapter, we share our experience and discuss the advantages and limitations of the project.

A Socioscientific Approach in the Design of the Module

The original WISE module begins with the story of Eric, a sick boy who intends to go hiking with his family. Our revised module, which was created in Hebrew, begins with introducing a newspaper ad, which reminds the public about a forthcoming CF donation day. In this ad (see Fig. 2.1) a real girl, Shefa, tells the public about her daily routine: one hour of physiotherapy, three inhalation treatments, 50 pills, controlled physical activity, special high calorie nutrition, and frequent hospitalizations. The ad culminates with the saying "For you it is a donation, but for us this is like air for the next inhale." We would like to note that in Israel, junior high school and high school students are requested to participate in door-to-door fund-raising for certain approved nonprofit organizations such as the CF, diabetes, and breast cancer organizations. In the revised module, after students are presented with the ad in the first activity, they are asked whether they would have volunteered to participate in such a CF fund-raising program. In order to make an informed decision, students are invited to learn more about CF. This opening dilemma is then reiterated as a final activity in the module, as we describe below.

Fig. 2.1 The opening page of the Hebrew CF module – Fund raising

As can be understood from the above description, right at the beginning of the module the students, who worked in groups of three, were requested to make a decision. In various other tasks, students were required to make decisions and provide arguments for their socioscientific decisions. After that, the students are referred to the Israeli CF nonprofit organization where they can watch a short interview with two boys and can get additional information about the disease and its treatment. By this point, the students begin learning about CF by suggesting questions for further learning, sharing their questions with their peers, and choosing together the questions for their investigation. Already in this first activity we encourage socioscientific reasoning (Sadler et al., 2007) and we highlight the need to make informed decisions that are based on social and scientific perspectives.

In the two additions we made, the hospital visit and the online interaction, we emphasized the opportunity to learn about CF patients' real life dilemmas. In the hospital visit, the students met a young female patient who told them about her everyday life and her after-school activities. One anecdote this girl shared with the students, in an attempt to indicate her relatively good condition was that she was not accepted to a "make your dream come true" program for children with major diseases. Her dream was to visit Disney World, but she did not qualify for the program because her condition was not considered as major. The students met a social worker who provided examples to the way she and the staff present the disease to the patients and suggest strategies to cope with it. She also presented them with tensions between the everyday lives of patients and their need to get continuous treatment. Students met a doctor who answered their questions about CF, heredity, and fertility, which had emerged as a topic of particular interest among many of the students. In the online interaction with the CF patient, students had an opportunity to interact with David, an undergraduate student, about his social life, his sports activities, and the way he manages to study engineering, get treatment, and lead a normal life, as he describes it. All these activities were in conjunction with learning the science behind the disease and learning about other inherited traits.

To sum up this section, in this study we explore how socioscientific issues provide learning opportunities in different contexts. A socioscientific issue can be presented in a text format, in an oral discussion, in a TV item or program, in a Web page or through any number of other channels. The use of socioscientific issues is intended to highlight the complex relationships between science and economical, health, environmental, and social issues, and they provide students with an opportunity to deal with real and relevant dilemmas. Our project involved teaching genetics in an everyday context, while engaging students in dealing with dilemmas of patients, parents of patients, and the general public. The students were requested to make decisions about social action (fundraising), about what should be done with such publically-raised funds, and about whether or not to try to prevent birth of sick babies (acting as genetic counselors), while interacting with real patients in person and online.

The Field Trip

Learning in out-of-school environments is common worldwide. Students get to visit science, natural history, and art museums. They visit zoos and have field trips to nature parks. There is much evidence in the research literature that out-of-school learning has many positive impacts on learning outcomes of various sorts (Bamberger & Tal, 2008; Falk & Dierking, 2000; Rennie & McClafferty, 1995, 1996). Students learn scientific content, develop positive attitudes toward science, interact with each other while being engaged in learning meaningful things, and gain opportunities to use all senses to experience phenomena in real-contexts (Dillon et al., 2006). Field trips can help students to visualize and understand controversial issues such as whether a wetland was dried to provide more land for farmers or to consider the positive and negative environmental consequences of farming (Tal, 2004, 2008). Field trips can also be used to enhance discourse and collaboration between groups in conflict. Tal and Alkaher (Tal & Alkaher, 2008, 2010) investigated multicultural environmental activities of Jewish and Arab youth in nature parks in Israel. Eighth graders from different cultures who speak different languages learned about development vs. conservation in a nature park in the region. The socio-environmental conflict had significant associations with the greater national conflict between Israelis and Palestinians. In our view, all these different types of field trips promote meaningful learning by situating learning in authentic contexts, providing hands-on experiences, embedding those experiences in issues, and accounting for the sociocultural dimensions of learning.

In order to carry out the field trip, we contacted a few CF units in Israeli hospitals. Fortunately, we got several positive responses, which allowed us to prepare a school visit that included the following components: (a) meeting a social worker, a nurse, a physiotherapist, and a doctor; (b) visiting the treatment unit, and experiencing some (real) tests and exercises that CF patients need to go through; and (c) meeting a middle school patient and talking with her about her everyday life. Based on principles of how to carry out educational field trips (DeWitt & Storksdieck, 2008; Orion, 1993; Tal & Morag, 2009), the preparation for the field trip included not only the science and health relevant topics. The students watched a short movie which was available at the CF association website that presented the CF unit and the staff. It happened that with no intention, the girl that appeared in the movie was the same girl that the students met at the hospital. Special attention was given, in the preparation, to ethics, and the students discussed what would be appropriate and inappropriate to ask the patients, to avoid unintended but possibly insensitive inquiries. Overall, the field trip lasted for 3 h. Throughout the field trip, Stella, who planned the visit, acted as a mediator. This function was crucial, as hospitals are not arranged for school visits. No one can know in advance what unexpected event could come up, whether the doctor will have enough time to talk with the students, whether the patient will be in the right mood to open-up to the students, how students will react to experiencing the actual tests on their own bodies, and many other possible challenges. As already mentioned, eventually, we were able to carry out all the planned activities, and even the young patient who was very shy at the beginning, eventually was very friendly and talkative and shared with students some of her life experiences. In school, after the visit to the CF unit the students continued working on the module and were challenged to draw the family tree of the CF patient they met. After this range of activities, the students resumed the more general tasks of the module.

Online Interaction with a Patient

Since computers have been widely introduced into schools in the 1980s, extensive evidence has accumulated showing that technology-based learning environments, when appropriately designed, can have a great impact on student learning of science (Pea & Collins, 2008). As internet access became more abundant in schools, much energy has been put in research and design of Web-based learning environments (e.g. Slotta and Linn, 2009). One important added value of these environments is their capability to allow students to break the boundaries of the classroom, and extend their interaction to include, in addition to their peers and teachers, people around the world who can widen their horizons regarding science topics they study in class (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). These interactions, of course, require careful preparation.

In the current study we decided to take advantage of the affordances of online environments in order to develop another version of the module that would serve as an alternative to the field trip. In many countries, including Israel, field trips in general, and a sensitive fieldtrip such as the one described above, are not easy to carry out (Dillon et al., 2006). To make the unit applicable for other places in the world – in which limitations such as lack of financial support (for transportation), difficulties in collaboration with a nearby hospital, or incapability of hospitals to allow such visits – we made a design decision to provide an alternative authentic experience to students. The online interaction version of the module included a forum, in which students had an opportunity to interact with a real patient. In a pilot study of this version of the module, students interacted indirectly with a nine year old boy. Due to his age, the interaction was indirect – the mother interacted mainly with the teacher (Stella), to answer the students' questions. In an attempt to avoid possible inappropriate or unethical exposure of a youth, we found a young adult – an undergraduate student whom we refer to as David – who was willing to collaborate with us. David was willing to participate in an asynchronous discussion with students within the WISE module, which lasted for about two weeks. He provided a brief personal background in the first posting in the forum and invited students to ask him questions. Each student group wrote a question in the forum. David made an effort to answer questions from each and every group. The questions that the students asked David demonstrate the various aspects they were concerned with, which include social, health, and scientific aspects. Examples of such questions are: "How does coping with the disease affect your life?"How much time per day are you occupied with treatment?" "Whether, and in what ways does the disease affect your social life?" "How did the disease develop when you turned into your teens?" "How many people in your family are sick?" "Are there any sick people or carriers in your family?" "Do you have concerns about passing the disease to your kids?" Some students continued with more questions, and David answered some of those as well. He told students about his sickness, his life history, his family, and his everyday experiences. We stressed that finding the right person for this work was challenging, and eventually, it was the CF unit personnel at the hospital who connected us with him. We also want to note that David suffered from depressions, due to his condition, and that he declared that interacting with the students was a therapeutic activity for him.

The Study

The study comprised three phases: a pilot study and two phases of the main study. The participants were 8–10 graders from a 6-year secondary school (grades 7–12) in Tel Aviv. This school serves a heterogeneous population of low to high socioeconomic status. Altogether, one eighth grade, one ninth grade, and two tenth grade classes participated in the study. Typically, simple inheritance is taught in Israel in the ninth grade, but in some schools it is taught in tenth grade.

In the *pilot study*, we used a version of the module in which we adapted the original WISE Simple Inheritance module to the Israeli context. This included changing the framework story of the module and the associated learning tasks. The adaptation was based on design guidelines for educational technologies found in the Design Principles Data Base (Kali, 2006; Kali & Linn, 2007), and specifically, a design principle which calls to "connect science to personally relevant contexts" (Kali, Fortus, & Ronen-Fuhrmann, 2008) was used. Stella was the teacher of a cohort of 41 students from one ninth-grade class, who participated in the pilot study. With respect to data collection, at that stage we collected descriptive data in the form of students' work as expressed in the "notes" function of the WISE module. We also documented students' reactions while working with the module, and we observed their work in small groups of 2–3 students. In addition, we used this phase to test our scoring rubrics and to examine and revise the open-ended reflection questionnaire and the Likert type feedback survey. Participating as both teacher and researcher, at this stage, allowed Stella, who knew her students very well, to identify issues that required design revisions, and to distinguish them from other issues related to the specific learning context. We refined the design of the adapted version of the Simple Inheritance module to improve usability issues. We also made some modifications to the scoring rubrics to make them more reliable.

The research questions that we pursued in the main study were:

1. What were the learning characteristics of the students who learned simple inheritance using the adapted Simple Inheritance module?
2. How did the two enhancements (the hospital visit and the online interaction with a patient) contribute to [a] the students' interest in genetics? [b] the understanding of scientific ideas in genetics?
3. Was there a difference between the two enhancements with respect to their contribution to the increase in the relevance of the module?

Following the pilot study described above, the main study included two stages: (a) enactment of the revised Simple Inheritance module with one class of 28 eighth graders (taught by Stella) to answer research question 1, and (b) enactment of the two additional versions of the module (basic + hospital visit and basic + online interaction), with two classes of tenth grade students (about 30 students each) to answer research questions 2 and 3.

In the next stage, two other teachers, guided by Stella, taught two tenth grade classes of about 30 students each, in which students had not studied genetics earlier. In this quasi-experimental stage, each class used the adapted module with one addition: either the hospital visit or the online interaction with the CF patient, David. The two classes were similar to one another in terms of student ability levels and female-male ratio; both were also heterogeneous with respect to student socioeconomic status. The additions were randomly assigned to the two classes.

Unlike in the USA, where teaching the module takes about two weeks, in Israel, due to fewer science classes per week and to holidays, it took the teachers more than a month to complete the same number of lessons. The additional activities required more time – 3 h for the field trip plus a preparation activity of about one class period, and about two sessions for the online interaction.

Data Collection and Analysis

Data collection included:

(a) A science-knowledge integration test, which was administered 1 week after students completed their learning with the module. The knowledge integration test that was designed to measure students' explanations was developed by the original developers in the WISE project in the USA (Benemann, 2005; Linn et al., 2006; Liu, Lee, Hofstetter, & Linn, 2008). Duncan (2007) revised the test from which we used three open-ended questions that examine students' integrated understandings of the principles of simple inheritance (see Appendix 1). To this test, we added another complex question that required students to apply their knowledge to a typical situation in Israel, in which many families of CF patients are uncertain about whether their ancestors had the disease as many large families were exterminated during the Holocaust.

(b) A feedback questionnaire that included two parts: six Likert type questions with four possible answers and two open-ended reflection questions (see appendix 2).
(c) The answers of the students to the written tasks in the module.
(d) Observation data collected throughout the four enactments of the adapted Simple Inheritance module.
(e) Evidence from students' work in the module; for example, to assess student engagement, we used the question about their tendency to participate in fund-raising for CF.

The knowledge integration framework was used to develop a rubric with a 0–5 point scale to assess student responses (on the science-knowledge integration test) in order to identify the number of incorrect, partial, and complete connections that students make (Liu et al., 2008). Levels 0–2 are considered low level scores: Score 0 indicates no response was given. Score 1 indicates that even though something is written, the response is off task. Responses that contain incorrect or irrelevant ideas or connections receive a score of 2. Levels 3–5 are considered higher level responses: A score of 3 means that students have relevant correct ideas, but fail to make connections between them. A score of 4 means the student response contains one basic scientifically valid connection between two ideas. A score of 5 is the highest score and must contain multiple valid connections between 2 or more scientifically correct ideas. The scoring levels were refined by careful analysis of student responses, so that they were distinct enough to differentiate students' reasoning, but at the same time capture all possible student ideas.

Differences between students' outcomes in the two conditions (field trip and online interaction with a patient) were calculated using a T-test procedure. As we could not make a normal distribution assumption, we compared between students' attitudes toward learning with the field trip vs. the online interaction by employing Mann–Whitney U test. This test is an alternative to the independent group t-test, when the assumption of normality or equality of variance is not met. Like other nonparametric tests, the Mann–Whitney test uses the ranks of the data rather than their raw values to calculate the statistic. In order to analyze the students' responses to the open-ended questions in the module, we were influenced by the work of scholars who studied student argumentation in the context of socioscientific issues (Hodson, 1994; Jiménez-Aleixandre et al., 2000; McNeill & Krajcik, 2007; Sadler, 2004; Sadler & Zeidler, 2004; Zohar & Nemet, 2002). We looked at students' claims and their justifications. For example, for a family tree task, in which the

Table 2.1 Scoring rubric for the family tree task (max = 4)

Claim	0 Inaccurate claim (CF is not a genetic disease)	1 Accurate claim (CF is inherited)	
Evidence	0 Uses the family tree diagram incorrectly	1 Referring to correct details in the family tree diagram	
Reasoning	0 No attempt to explain the relationship between claim and evidence	1 Insufficient explanation	2 Provides accurate reasoning that ties the evidence to the claim

students were requested to predict which family members will carry the CF gene, we used the rubric presented in Table 2.1. In this task the students had to present a claim with respect to heredity of CF. This claim was supposed to use the evidence, which was their own drawing of the family tree based on given textual data. In their justification, they had to tie the claim and evidence.

A few examples for scoring students' answers are:

"CF can be genetic disease since one of the ancestors of the family was sick" [claim-1; evidence-0 (inaccurate tree); justification-1 (partial)]

"CF is indeed genetic because in the family tree we found that descendants in the family have the disease in different generations"
[claim-1; evidence-1 (referring to correct family tree); justification-1 (insufficient, does not refer to both sides of the family)]

"Yes, CF is inherited, but we don't know in which generation it develops" [claim-1; evidence (tree)-1; justification-0]

"Yes, CF is inherited because you can see other two sick family members in both side of the family"
[claim-1; evidence-1 (correct tree); justification-2 (refers to sick people on both sides of the family)]

It is important to note that students created the family trees based on textual information in order to generate evidence for supporting claims regarding CF. Given that they never saw such a diagram prior to this task, the task was quite sophisticated.

Outcomes

Interest and Engagement

In answer of our first research question, we found that the vast majority of the eighth grade students expressed interest and enjoyment regarding the WISE Simple Inheritance module referring to their comfort in using technology. This was indicated in several ways. In the open-ended reflection question of the feedback questionnaire, many students noted that they preferred the "notes" function in the online module than writing in physical notebooks, which they usually use in biology lessons. In addition, several students addressed the new ideas they learned. One student, for example, wrote: "Working with the web-based module has enriched me with new knowledge. Now I know things and concepts I did not know before." Another student indicated: "I think computer-based learning is good, since kids are taught in a way they are familiar with and it is more creative and fun. I think it helps kids open their minds." Other examples from students' responses in the feedback questionnaire, indicate students' increased interest following their learning of the module: "we want to learn [look] more closely on information about CF, we want to understand more specifically, why this disease is more problematic than other [diseases]"; "all this probability thing and the looking on our ear lobes was interesting." Only one student stated in the open-ended question that the module was not interesting.

In our observations, we found extensive evidence for increased interest in genetics among the students. While learning from the module, many students asked the teachers for recommendations of websites dealing with CF in addition to those provided in the module. A few students who did not find satisfying answers in the module approached "BaShaar" – a nonprofit scientists' organization for the Israeli society, that has an "ask a scientist" forum in its website.

Another piece of evidence for students' deep engagement came from a task we added to the original module in an attempt to increase relevancy and encourage reasoning activities. In a short paragraph, we described a young couple expecting a baby. This couple found out that they both carry the gene for CF, which means they have a 50% chance of having a sick child. The students were asked to "Imagine that you are a genetic counselor, what you would recommend to this couple?" After a short whole-class face-to-face discussion, students were required to write their recommendations. We observed the students enthusiastically negotiating and debating this task. The variety of student answers indicated they understood the sensitivity involved. There were students who argued that the genetic counselor should only give the scientific and health information, with no recommendation regarding a particular decision. One group suggested that the counselor should help the couple better prepare themselves for the situation: "They should learn about CF, for any case, so they won't be surprised and in order to face all the challenges." Another group suggested examining the fetus: "it's 50%, so it's a chance the baby will be healthy, but if they know it's a sick baby, we would recommend an abortion." A different group was convinced that the counselor should work with the couple on how to accept a sick child with love and provide the best possible treatment. It was hard to stop this discussion, which involved what the students learned as well as their personal values.

One more activity that aimed at increasing relevancy was the fundraising activity that served as an opening and summarizing assignment in the adapted module. In their responses to this task, the students expressed empathy, and referred to their responsibility as citizens.

> After we learned about CF, we realize that the public awareness is not sufficient, so we would like to participate and contribute to increasing awareness (gr. 2).

In the post-task the students were asked to provide a recommendation using the money raised. In their answers, the students not only addressed scientific research but also included better equipment and facilities for patients. They advocated for establishing cross country services for parents, which would make their own lives easier, support groups for future parents of sick babies to prepare them and help them in the first months, and fun activities for sick youth.

> We'll go out [to participate in fundraising] because [cf] is actually a chronic disease… it is important that the patient will have the best possible quality of life, and that can be achieved by physiotherapy and donations of people who think it's important.

We observed not only within group discussions about the different purposes, but we also saw many between group discussions about this issue. Evidence from students' work in the module and the observation data indicated deep engagement on the part of students and thoughtful group discussions that were the result of enhancing relevancy and including controversies in teaching the Simple Inheritance module.

Contributions of Field Trip and Online Interaction

To answer the second and third research questions, we describe and compare the contribution of the two enhancements (online interaction with a patient and the visit to the hospital) to students' interest and understanding of scientific ideas in genetics. The analysis of the open-ended responses to the question "In what way/s has the online interaction with David contributed to your learning of genetics in the Simple Inheritance module?" allowed highlighting the contribution of this addition to students' learning (research question 2). A few topics emerged in the students' responses that elucidate this contribution. Major themes are identified below with quotes excerpted from questionnaires that students completed following the experience:

The ability to ask questions improves learning. "The talk with David, in the forum allowed me to ask him questions that interested me about how he copes with the disease. It helped me learn the topic."

Learning new things. "Although his answer to my question was not very clear, he told us many things we did not think about so never asked about."

Understanding the patient challenges. "Talking with David helped me realize what these people go through every day."

The responses to the same question that addressed the field trip provided stronger evidence for the field trip supporting meaningful learning and in general, were more clearly articulated. The topics that emerged were:

Complementarity. "Learning through the CF module and the field trip complemented each other, because things that were in the module were not in the field trip. Both were interesting and contributed."

Meaningful learning. "I learned some background about the disease, which helped me understand the topic. When I wrote my answers in the module, I wasn't sure, but when I went back to the module after the hospital visit, it was more interesting and I better understood"; "No doubt, the hospital visit helped me learning. The presentation of Diana (the social worker) provided many details on the disease and how kids cope with it in their daily lives. The meeting with the sick girl - it certainly helped me to prepare for the test."

Relevancy. "I have two sick friends with CF. Through learning with the module, the field trip and the staff's presentation, I now understand what happens in the disease and what the patients go through every day. While we can do everything we want, they have to do inhalations, eat enzymes…"; "Being there at the hospital and observing the daily routine certainly clarified the stuff. The presentation and the questions we asked summarized the topic perfectly."

While the students who were engaged in the online interaction addressed mainly affective contributions, the students who visited the hospital referred to deeper learning and understanding, as well as to affective contribution of the visit. Moreover, they better connected the out-of-school experience to learning with the module. An analysis of the contribution of the two additions to student learning, as reflected in the sophistication of their responses is presented in Table 2.2.

Table 2.2 indicates that the hospital visit was better perceived as a contribution to the students' learning than the online interaction. The vast majority of the students who visited the hospital provided detailed arguments for why and how the visit helped them learn genetics. The "interaction students" addressed mainly affective aspects in their responses, and more than one-third acknowledged the contribution of the online interaction to their learning only to a limited extent.

As indicated, another way in which we analyzed student engagement was exploring a question about the students' tendency to participate in fundraising efforts for CF. Students worked in groups to negotiate this issue, and our analysis focuses on social responsibility, acquired knowledge, and affect. Table 2.3 presents the classification to the three justification levels described above.

Prior to learning the Simple Inheritance module, 8 groups out of 18 gave poorly justified answer to the question posed compared to 4 groups that gave such an answer at the end of the module. Only 1 group provided a response characterized by the highest level of complexity at the beginning compared to 5 groups that provided a well-established response at the end. More groups of students who visited the hospital provided the highest level of responses than the students who participated in the online interaction. These responses incorporated statements about what they learned or/and what they felt about taking part in fundraising. This is another evidence for stronger effect of the field trip.

Knowledge Acquisition

As noted above, student knowledge acquisition was assessed by: (a) the knowledge integration test developed by the WISE group at Berkeley, (b) another open-ended item that we added to this test (item 4), and (c) analysis of the responses

Table 2.2 Analysis of student answers regarding the contribution of the online interaction and the field trip to their learning

Answer orientation (positive vs. negative) and justification		Example	Frequency (%) Online interaction (*N*=22)	Field trip (*N*=28)
Negative	Unjustified	N/A	4	
Negative	One justification	Talking with David did not help me understand genetics better, it only helped understanding his everyday functioning (online interaction) No, talking to David did not help me understand, while seeing his family tree helped better (online interaction)	19	0
Limited contribution	At least one justification	Not much, since David did not add anything new. He mainly talked about how the disease affects his life. What he did add was that he explained how a carrier or a sick person calculates the odds of a sick offspring, so David will not have kids with a carrier (online interaction) Not so much, because the visit took place after we completed most of the module, but it did help me connect what we already learned (field trip)	14	4
Positive	Generic or one justification	Yes, David helped me understand the disease characteristics Yes, because learning in school with the teacher – the routine, is less effective than real interacting with patients (field trip)	53	69
Positive	A claim and detailed justification	Talking with David in the forum helped because he explained about CF, and answered the question that interested me such as… (online interaction) Yes, the field trip helped learning the subject. In the hospital, they showed a presentation that gives clear explanation of the disease. For example, we learned that in order to increase their life expectancy the patients need high calorie diet, they need to consume enzymes to catalyze the fat, practice out, do physiotherapy and inhalations… we were physically much close to the whole thing, and it made us want to learn more about the disease, its symptoms, cure and so forth (field trip)	10	27

Table 2.3 Justifications for fundraising activity

		Frequency			
		Online interaction		Field trip ($N=10$)	
Justification	Example	Pre ($N=8$)	Post ($N=6$)	Pre	Post
Unjustified generic response	Yes, we agree to participate (in the fundraising program) in our free time	2 (25%)	3 (50%)	6 (60%)	1 (10%)
Justified response supported by sense of responsibility expression of feelings OR acquired knowledge	Yes, we will participate, as we understand how severe the disease is	6 (75%)	2 (33%)	3 (30%)	5 (50%)
Justified response supported by sense of responsibility that addressed acquired knowledge AND affect	Yes, it's important for us to save lives, and now we care much more, because we know about CF symptoms	0	1 (17%)	1 (10%)	4 (40%)

to questions that students answered using "notes" in the Simple Inheritance module. In this section, we present the outcomes from the analysis of these three data sources.

Knowledge Integration Test

Figure 2.2 shows students' responses to items 1–3 in the test. As can be seen from Fig. 2.2, the differences between the online interaction group and the field trip group were not large in magnitude. The differences were not statistically significant.

The additional question developed for the Israeli version of the knowledge integration test (item 4), required students to suggest why many CF patients in Israel have difficulties in identifying members from their larger families who had CF in the past. The complete answer to this question could include a few possible reasons: In past generations, especially in underdeveloped countries where many of the Jews lived, it was common for individuals not to know the accurate reasons for why death occurred at early ages. In particular, with the case of CF, many deaths were attributed to pneumonia and other infections. Being a recessive disease, it was also possible that there was only evidence of carriers (and no evidence of diseased individuals) in the immediate past generations of a family. A third possible reason for this lack of knowledge can be attributed to the Holocaust. Many family lineages were almost extinct and in general, the ability to know the life circumstances of ancestors is limited. The main themes that emerged from the analysis of students' answers to question 4, with respect to the reasons for the scarce knowledge base

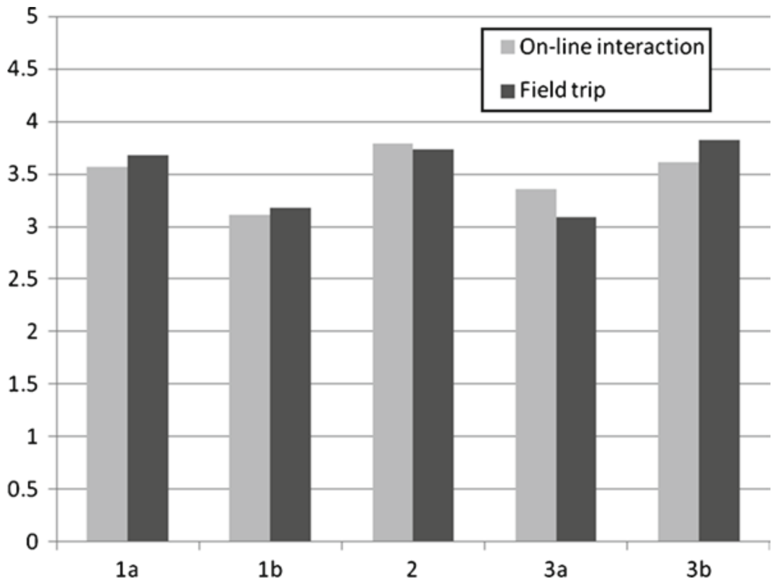


Fig. 2.2 Scores of the test items (max = 5)

about sick relatives of CF patients were: (a) insufficient awareness of the disease and lack of advanced technological means in the past for diagnosis and treatment, (b) low probability of having the disease, and (c) insufficient family background information due to the Holocaust (although this response was only offered by one student). Interestingly, the distribution of students' answers, as presented in Table 2.4, indicates more genetics-based justifications from the online interaction students (55%) in contrast to more justifications related to technology, diagnosis, and awareness brought up by the field trip students (55%). In other words, while the majority of the online interaction students based their answers on the scientific aspect, the majority of the field trip students founded their answers on the social-technological aspect. Additionally, Table 2.4 shows that irrelevant answers were provided by more field-trip students than by online interaction students.

Simple Inheritance Module Notes

One example of the Simple Inheritance module tasks was the family tree task, in which students had to predict how a sick child "got" the disease. The categories we employed (Table 2.1) were: (a) claim (wrong/correct); (b) evidence (correct /incorrect tree); (c) justification (explaining the claim based on the information from the family tree). Table 2.5 presents the distribution of responses of the groups of students who studied with the two enhancements. The maximum points available for each group was 4, and the number of groups was eight in the online interaction version and 10 in the field trip.

Table 2.4 Answers to the Israeli-context item about history of CF patients

Type of response	Online interaction (*N*=22)	Field trip (*N*=29)	Examples
Difficulties in diagnosis and poor technology; lack of knowledge about the disease	9 (41%)	16 (55%)	• There was no awareness to the disease and no treatments • People died at early age of various reasons including CF with no distinction • Many Ashkenazy families were exterminated in the Holocaust, so no one really knows
Probability of having sick people is low; more people being carriers than sick	12 (55%)	8 (28%)	• Probably, in past generations in these families there were only carriers • As the probability (to be sick) is not high, because it's a recessive trait, the disease did not express • The disease was not known then, so • people were not diagnosed properly, and their death was attributed to something else
Not relevant	1 (4%)	5 (17%)	

Table 2.5 Distribution of the answers to the family tree task

	Claim		Evidence		Justification		
Rank	0	1	0	1	0	1	2
Online interaction (*N*=8)	3.375	5.625	4.5	4.5	30.375	1.125	4.5
Field trip (*N*=10)	2.2	8.8	2.2	8.8	1.1	5.5	4.4

The distribution of the answers shows some advantage to the field trip students with more groups providing accurate claims, suggesting correct family trees as evidence and more groups justifying the claims with the tree-evidence. Outcomes of multiple choice items, embedded within the module that enabled us to assess students' understanding of the concepts of genotype/phenotype and recessive/dominant genes revealed no difference between the two enhancements. Overall, using all the data available to us, there seems to be no significant gap between the performances of the online interaction group and the field trip groups regarding knowledge acquisition.

Student Attitudes

Comparison between students' attitudes toward learning with the module with each of the two additional components was carried out by employing Mann–Whitney's *U* test. The results are presented in Fig. 2.2; the term "addition" in the figure refers to each of the two additions: the online interaction or the field trip.

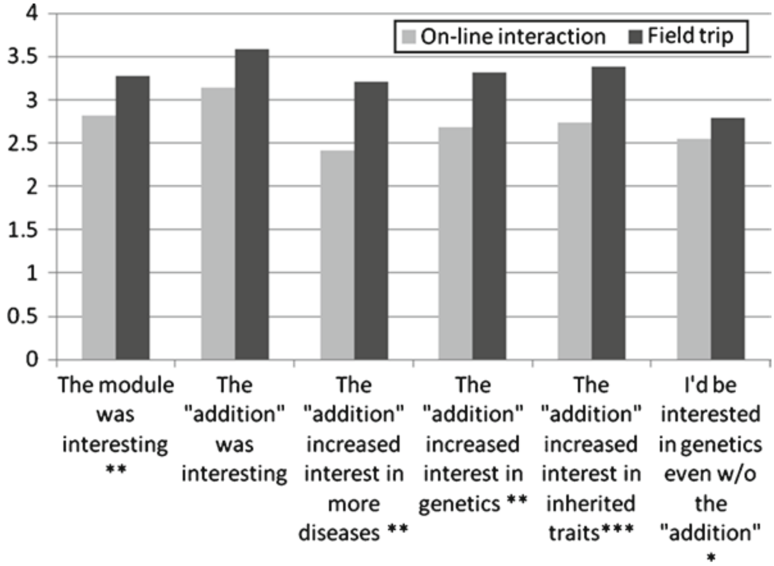


Fig. 2.3 The students' attitudes toward learning with the online interaction and the hospital field trip

Figure 2.3 shows that in most items, field trip students expressed attitudes that were significantly more positive toward the module than the online interaction students.

A brief summary of our findings shows that: (a) the adapted module, even without the additions, created interest and motivation among students to learn about genetics, (b) the field trip addition was more productive than the online interaction addition in enhancing student interest and self-viewed learning, and (c) no differences were found in students' knowledge acquisition as measured by the test and the module tasks when learning with the modules with each of the two additions.

Discussion

The findings described above show that the design of the adapted module, even without the additions of the field trip and the online interaction with a patient, was successful in getting students interested in understanding the science behind the CF disease. The findings indicate that features in the project, such as incorporating the real story of Shefa, involving students in making decisions (even though these were fictitious decisions) about whether they would participate in a fundraising program, or what they would recommend to a family confronted with the possibility of having a baby afflicted with CF were crucial in getting students engaged and promoting their interest in understanding genetics.

Relating science to personally relevant contexts is a well-known instructional strategy for designing learning environments that can make science accessible (see for example Duschl, Schwiengruber & Shouse, 2007; Linn, Davis, & Bell, 2004; Kali et al., 2008). In fact, the design of both the original module and the adaptations introduced into the module for the Israeli audience described in this chapter, were based on this design principle. This design principle is very much in line with some of our previous work, in which we aimed at increasing student engagement in science by developing learning materials, which were based on STS ideas and incorporated a variety of socioscientific issues about genetics, and the Mediterranean coast environment (Dori et al., 2003; Tal & Kedmi, 2006). Nevertheless, we view the contribution of the current study, in enabling a critical analysis of means for enhancing authenticity. By comparing what students thought of their learning with each of the additions to the module that were designed to increase authenticity, we were able to closely investigate what it is that makes successful or less successful means of increasing authenticity. We would like to stress that we do not view this comparison as one that would enable us to say that either field trips or online interactions are superior means of increasing authenticity. This would be an oversimplification of our findings. Rather, we take a design stance (see for example Kali & Linn, 2007) to make sense of our findings. Since we have two designs, the field trip-enhanced module and the online interaction-enhanced module; the first which elicited a higher degree of interest and engagement among students than the latter, we can identify important design elements that support science learning in socioscientific contexts. In the next sections we elaborate on these design elements.

Diversified Interactions

As described above, during the field trip, students had an opportunity to interact not only with a CF patient, but also with a social worker, a nurse, a physiotherapist, and a doctor, and to experience real tests and exercises that CF patients need to go through. The online interaction on the other hand, was limited to interaction with David, the CF patient. We assume that the diversified interactions in the field-trip enhancement were highly important in providing students with a holistic understanding of this socioscientific issue, and thus, brought to increased authenticity. This assumption is based on several findings: (a) answers to the open-ended question provided by the field trip students, which indicated a stronger connection to the genetics contents than those provided by online interaction students, (b) the hospital visit that was better perceived as a contribution to the students' learning than the online interaction (Table 2.2), and (c) the stronger, and more content-related justifications that field trip students provided in the fundraising activity (Table 2.3). An improved design can definitely include such diversification, even when constrained to a web-based module. We suggest that adding relevant clips to the online environment (such as clips of practitioners or practices in the field), with prompts for reflection or discussion, can provide students with additional aspects and a broader picture of the topic they are exploring, and also to capture a bit of the authenticity of a field trip.

Live Communication

During the field trip, students were able to communicate with all the people described above in real life. Such social interactions are advocated in the informal science education literature (see for example Ash, 2004; Bamberger & Tal, 2008; Schauble et al., 2002). Asynchronous discussions have the advantage of enabling students to carefully articulate their thoughts, and to reflect before replying. This is definitely an added value in many curricular settings (Hoadley & Linn, 2000). However, based on the same findings indicated in the *diversified interactions* design elements, it seems that in the particular setting of the current study, and perhaps in other SSI, when one of the goals is to engage students emotionally, the disadvantages of asynchronous discussions, which lack the dynamics, the body language, and the liveliness of a face-to-face discussion, are more dominant. An improved design in a technology-enhanced solution, could take advantage of synchronous meetings with people in the field, preferably with audio and video.

Time on Task

The field trip, which was a half-day event, and was preceded by a preparation in class (DeWitt & Storksdieck, 2008; Orion & Hofstein, 1994), required more time than the online interaction, which took place in about two teaching sessions (of 50 min each). Although this might sound obvious, in an atmosphere in which schools are pressed by high stakes measures, teachers are discouraged from devoting time to topics that are not included in the core curriculum or face too many organizational challenges (Dillon et al., 2006; Tal, 2008). We find it important to note that productive socioscientific activities can be time-consuming. When students spend more time on getting to know the details of a real-world problem, they have the opportunity to perceive the complexities involved, and get a realistic sense of the scope of the problem they are studying.

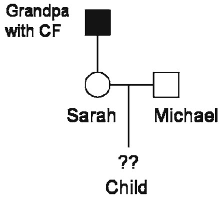
Another interesting finding of this study is that although there was a significant difference between the way students in the two groups (fieldtrip and online interaction) perceived their learning with the module, there was no difference in their knowledge acquisition. However, even though a connection between student interest and knowledge acquisition was not found in the current study, it does not mean that such a connection does not exist. We believe that when students are more interested and engaged, they will explore the problem that they are studying in greater depth. If they are scaffolded properly, there is a greater possibility that they will develop the mental connections required for understanding complex science, and integrate the pieces of knowledge to a coherent and integrated understanding (Blumenfeld, Marx, Patrick, & Krajcik, 1997; Roseman, Linn, & Koppal, 2008; Singer, Marx, Krajcik, & Clay Chambers, 2000; Solomon & Thomas, 1999). One explanation to the lack of such a connection in the current study, is that in both cases, student interest and engagement were high (they were high even before we added the field trip and online interaction enhancements). Perhaps the difference in interest found between the two enhancements was not large enough to show a difference in their knowledge acquisition. Another possible reason for not finding this difference can be attributed to timing of the field trip. Orion (1993) argues that in order to get the maximum effect on learning, the field trip should be carried out at the beginning stages of the learning unit. However, due to organizational constraints, we were able to carry out the field trip only toward the end of the unit. In any case, we would like to stress that we view the goal of enhancing student interest not only as means for supporting their understanding of complex topics but also as an educational goal per-se, especially when socioscientific issues are involved. The literature shows that learning socioscientific issues contribute to the development of a wide range of higher order thinking skills (not necessarily those we assessed in the current study), promote learning of the nature of science, and encourage good citizenship (Dori et al., 2003; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004, 2005; Tal & Kedmi, 2006; Zeidler & Sadler, 2008).

The three design components articulated in this study, together with the design principle "Connect to personally relevant contexts" (Krajcik, Slotta, McNeill, & Reiser, 2008), which served as a basis of the design of the Simple Inheritance module, are crucial for designing science instruction in the context of socioscientific issues. That said, we would like to stress that we view the educational field trip itself, as an instructional strategy, which serves as excellent means to support the instruction of socioscientific issues. We would like to encourage educators to make the effort involved in having students augment the learning that occurs in class with outdoor experiences. However, we are also aware of difficulties involved in taking students to educational field trips. Thus, we recommend educators to take advantage of online authoring environments, such as WISE and others, in order to design productive online teaching activities for socioscientific issues that build on the design components identified in the current study.

Appendix 1. The Knowledge Questionnaire

1a. Sarah and Michael are going to have a baby. Both of them are completely healthy, but they know that Sarah's dad (the baby's grandfather) has a genetic disease called cystic fibrosis, which affects the lungs. Should they be worried about their child being born with cystic fibrosis?

(Choose one) ____Yes ____No

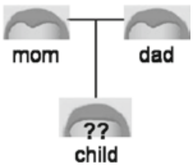


1b. List two pieces of information you need in order to accurately predict the chances that Sarah and Michael will have a child with cystic fibrosis?

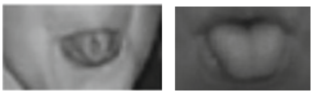
2. There are two main phenotypes (physical appearance) for the trait for hairline, which is a genetically inherited characteristic:

Or

Look at the family tree below; is it possible for two parents with widow's peaks to have a child with a straight hairline? **Explain why or why not**.



3a. Some humans have a trait (characteristic) for curling their tongues. You observe that a mother and father can curl their tongues, but their child cannot. Which of the traits below is the dominant trait?



(Choose one) ____Tongue-Curling Ability ___No Tongue-Curling Ability

Please explain how you determined this.

3b. What is the probability that these parents will have a child that will have the tongue-curling ability?

Explain how you got your answer.

In the SI module you got to know a few CF patients. According to the information that X gave, he is the only person in his large family known to have CF. Today, in Israel, in most families of CF patients no one knows about sick relatives in previous generations. Can you suggest a reason for that?

Appendix 2. Attitude Survey

	Do not agree at all	Not agree to some extent	Agree to some extent	Fully agree	Comments
Learning with the SI module was interesting					
The field trip[a] to the hospital was interesting					
The field trip made me learn about other inherited diseases					
Talking with the patient made me interested in how traits are being inherited					
I was interested in genetics even without the visit to the hospital					

[a]In the online interaction version, the words field trip were switched by "the online interaction"

Did the visit to the CF unit at the hospital, meeting with the patient and the staff contributed to your learning of genetics in addition to the SI module?

Please write any feedback or comment about the SI module and your own work

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