2.4: Cognitive engagement, societal relevance and direct interactivity when introducing ecogenomics in schools: Perceptions of students, teachers and scientists

Abstract

This study aimed to gain insight into how scientists, teachers, and students perceive the possibilities of introducing new scientific developments, in this case ecogenomics, in schools. For this aim, the three groups of participants were interviewed about three main issues: (1) students’ cognitive engagement in the introduction of ecogenomics, (2) societal relevance of ecogenomics and motivations to become involved in science communication, and (3) the potentially added value of direct interactivity between the three groups. Results showed that each of the three groups were positive about introducing new scientific developments at school resulting in cognitive engagement of students, not only societal but also personal relevance would be at stake, and direct interactivity would be of added value, although realization could lead to practical problems.

Note: This paper is submitted to be published as: Bos, Maasdijk, Koolstra and Willems “Cognitive engagement, societal relevance and direct interactivity when introducing ecogenomics in schools: Perceptions of students, teachers and scientists.”
Mass media have always had a predominant role in introductions of emergent technologies to the general public. The predominantly one-way mode of communication that is inherent to media such as newspapers and television, however, has also been criticized. In response to this criticism, there has been increasing attention for more interactivity in science communication. Van der Auweraert (2008), for example, suggested that there is an increased need for public engagement and participation, especially when a science issue is complex and controversial. Additionally, local knowledge and experience among publics should have an important part in information transaction. Other authors have emphasized that publics’ needs, interests, levels of (existing) knowledge about science and their attitudes toward it should be recognized, as well as the societal contexts within these publics are confronted with the issue at hand (e.g., Lewenstein, 1998; Einsiedel, 2000; Willems and Regeer, 2009). A shift toward more interactive modes of communication may also shift the existing tenets about the relation between media coverage and public opinion of science and technology (as suggested by Willems, 2003).

Past research has predominantly focused on how the mass media present science and technology (e.g., Bucchi and Mazzolini, 2003; Cook, Robbins and Pieri, 2006; Dearing, 1995; Hansen, 1994) and on how the general public or target publics respond to these issues (e.g., Gutteling, 2002; Lee, Scheufele and Lewenstein, 2005; Scheufele and Lewenstein, 2005). As summarized by Lewenstein (2005), this had led to some general tenets: Media stories generally focus on controversy and provide fewer details than scientists would like to see represented; the public does not know much about science in general or about the particulars of certain issues, but is generally supportive of science and technology; and scientists and journalists often disagree about what questions should dominate in media stories. An increased level of interactivity between experts and non-experts is expected to circumvent certain communication barriers that currently exist, such as the disagreement between scientists and journalists and the inaccessibility of scientists for publics.

The interactivity model depicts science communication as a receiver-oriented, process-based, and two-way or multidirectional process in which the public is an active participant who makes use of his/her existing knowledge and previous experiences to contextualize the new science information. (This in contrast to the scientific literacy model, that depicts science communication as a sender-oriented product-based and one-way process in which the public was considered a passive consumer of science information that held negative attitudes toward science because of a knowledge deficit – very bluntly put. For an extensive overview of the two models, read for example Burns et al., 2003; Logan, 2001; and Van der Auweraert, 2009).

According to Logan (2001), however, the interactivity model still recognizes that (1) there is a knowledge gap between experts and non-experts, (2) different actors
have different roles to play in this communication process, (3) it is beneficial to perform science communication and (4) these benefits may include the development of more positive attitudes toward science among publics. Logan posed that the two models are not necessarily mutually exclusive and that the interactivity model underlines rather than replaces the traditional scientific literacy approach. This study aims to investigate how people perceive the potentially added value of interactivity in communication about an emergent technology.

This study

Previous research has shown that schools are an interesting environment for science communication and that teachers may play an important role as intermediates (e.g., Weigold and Treise, 2004). This study also considers young people an interesting target public for science communication. One reason is the apparent lack of interest in, or low cognitive engagement with, science among young people. Young people have been shown to find science and technology difficult to understand and career-options in science unsatisfactory (Sjøberg and Schreiner, 2006; Van Sark and Den Hartog, 2004). Various authors have argued that there is a need to rekindle young people’s interest in science and technology because of the decline in enrolment of students in science and technology studies (Brandi et al., 2005; Mares, Cantor and Steinbach, 1999; The Dutch Ministry of Education, Culture and Science, 2009; Van Nes, 2004).

An enhanced understanding of young people as a target public for science communication is necessary because this group experiences the world differently that adults do, they interact in different ways, and they have different interests and priorities (Van Nes, 2004). Therefore, modes of communication that are suitable to reach an adult audience may not be best suited for younger people. In example, Shah and colleagues (2001) stated that while for older generations the traditional print and broadcast predominate as news sources and the Internet may be considered only a supplementary source, the reverse holds true for younger generations. Despite their intensive use of many different media, Van Sark and Den Hartog (2004) stated that these media-use behaviors have necessitated young people to be selective and that, as a result, they have developed a strong preference for information that adheres to their personal needs. In this light, perceived societal relevance of science may have an important impact on young people’s perceived need for information, their actual information-seeking behaviors, and the development of their understanding thereof. Van Nes (2004) also noted the manner in which science is communicated may inhibit young people’s cognitive engagement with, and their perceptions of societal relevance of, science because of the strong focus on cutting-edge developments, future applications, and use of scientific jargon.
In this light, when introducing emergent technologies to young people another mode of science communication seems better suited than that through mass media such as newspapers. Willems (2003) suggested that science communication may benefit from an interactive approach that brings scientists and publics into direct contact. Previous research has shown that young people prefer the use of the Internet when informing themselves about emergent technologies (Bos, Koolstra and Willems, 2009), especially so when engaged in school assignment or homework tasks (Ebersol, 2000; Weigold and Treise, 2004). One reason for this preference may be that young people enjoy the interactivity afforded by this medium as they have previously experienced in entertainment contexts (e.g., peer-to-peer interactivity during chat sessions or online games).

Also, and in contrast to interactivity between scientists and journalists, it may be that interactivity between scientists and teachers is easier to establish and maintain. This may be because the barriers that exist between scientists and journalists, namely the individual characteristics and professional cultures (Peters, 1995; 2005; Willems, 1976; 1998), are less apparent between scientists and teachers: Most science teachers have similar educational background as scientists. Following the suggestion of Weigold and Treise (2004), this study poses that teachers may fulfill an important role as intermediates in establishing and maintaining direct interactivity between scientists and young people.

Based on definitions derived from the literature (Kiousis, 2002; Liu and Shrum, 2002; McMillan and Hwang, 2002; Rafaeli, 1988), this study defined interactivity as the extent to which people are willing and able to contribute to the transaction of information as a purposeful process in which all participants may act on each other, the medium, and the content of messages exchanges. The study investigates the extent to which young people are an interesting target public for early introductions of emergent technologies and whether schools are a suitable environment for this. Following the suggestions of Weigold and Treise (2004), this study explored the potential of teachers as intermediates between scientists and young people. The emergent technology that was introduced to young people was ecogenomics.

Ecogenomics is a technology-oriented field of research that studies ecosystems at their genetic level. It makes use of genomics-like techniques that enables researchers to study multiple genes at once through extensive use of microarrays and bioinformatics. In the Netherlands, ecogenomics is aimed at unlocking the (genetic) potential for sustainable use of ecosystems for agricultural purposes (Ecogenomics Consortium, 2009). The subject of ecogenomics was considered interesting because it is still in a very early stage of development and had received little attention in public media at the time of research. Another reason is the multidisciplinary character of ecogenomics: it is “a new area of research and innovation that is positioned on the crossroads of molecular biology, biotechnology, ecology, soil- and environmental sciences” (Ecogenomics
The studies of the Ecogenomics Consortium, 2009), that may be difficult to understand for people unfamiliar with or uneducated in any of the adjacent fields of knowledge. Finally, ecogenomics has both environmental and industrial/technological aspects toward which the public may hold very different attitudes.

Method

Sample

A purposive sample consisting of eight scientists, seven teachers and twelve students ($N = 27$) was used. Participants were interviewed and all interviews were conducted at a place of the interviewees’ choosing; for the scientists generally their offices, for teachers and students generally their respective schools. Interviews with scientists lasted between 30 and 60 minutes ($mean = 45.54$ minutes); with teachers between 30 and 70 minutes ($mean = 42.08$ minutes); with students between 15 and (just over) 30 minutes ($mean = 23.56$). All partaking scientists were ecogenomics experts; all partaking teachers taught biology at a pre-university level; all students were enrolled in their pre-final year of school, at the pre-university level, and followed biology classes. A total of (just over) thirteen hours of audio-materials was collected.

Procedure

The interviewees were informed that the study aimed to investigate their perspectives on students’ cognitive engagement when introduced to the issue of ecogenomics, societal relevance of this emergent technology, and the potentially added value of direct interaction between them. Because teachers and students were expected to be unfamiliar with ecogenomics, they received a brief description of what it is and of the main themes and research aims of the Dutch Ecogenomics Consortium’s research program. This information was derived from the consortium’s website and was checked for factual correctness by an ecogenomics expert.

All interviewees were informed that participation was voluntary and that they could refuse to answer questions and/or end the conversation at any time. In an attempt to create an open atmosphere, it was emphasized that this was an exploratory study, that there were no right or wrong answers, and that we were interested in (creative) ideas, perceptions and feelings rather than in factual knowledge. Consent to recording the interviews was asked before commencement.

The interviews were semi-structured and revolved around three main themes: Perceptions on students’ cognitive engagement were investigated by asking interview-
ees to briefly describe how they thought about ecogenomics and how (they thought) students would search for information about ecogenomics. Perceptions on societal relevance were explored by having the interviewees reflect on the degree to which they thought (students would perceive) ecogenomics as being relevant for society. Perceptions on the potentially added value of interactivity between the three groups were explored by having the interviewees reflect on current efforts of science communication, personal thoughts on how to communicate about ecogenomics, and possible (lack of) opportunities for and (un)desirability of direct interactivity in future efforts.

The interviews were executed by the second author. All audio-files were later transcribed according to a question-answer model. These transcripts, along with the interviewer’s personal notes made during the interviews, provided the data used for analysis. The first author carefully read the transcripts to identify key ideas, words and phrases in search of trends (per group and/or overarching) and listened to the audio-files to check for possible lapses. As suggested by Ayres and colleagues (2003), distinctions were made between findings relevant for individual groups and across groups.

Results

Cognitive engagement

Perceptions on ecogenomics

Scientists were well able to reflect on their perceptions on ecogenomics. Most scientists predominantly focused on the process of research itself, in example ecogenomics was indicated to be about “using genomics to understand ecosystems” in general, or about “gaining insight in functions of ecosystems, using DNA, RNA and proteins derived from species in various ecosystems” more specifically. Others, however, focused on its technological character and applicability, in example ecogenomics was indicated to be about “the state of soils, healthy or not, and to monitor and improve them using state-of-the-art technology,” to include the use of “the new [technological] possibilities of molecular science in ecological contexts to study, describe and control ecological systems” and to be applied “to measure soil quality.”

Teachers were found to have some difficulty in providing insight into their perceptions on ecogenomics, but were nonetheless well-able to provide general descriptions. Three example statements were that ecogenomics is about “how genes and DNA have their influence on the organisms and the relations between organisms and their environment” or “examining the genetics of organisms to gain more insight into ecosystems” and “the use of DNA techniques for detection of ecological problems.” One teach-
er described ecogenomics as “a new and promising branch in biology that shows how knowledge becomes increasingly intertwined and that this is necessary to move forward.”

STUDENTS. Students were also found to have some difficulties in describing their perceptions on ecogenomics and provided more general descriptions than teachers and scientists. One student expressly stated that this question was difficult to answer and formulated the answer as a question: “how to use plants and micro-organisms for new developments for humankind?” In general, students perceptions on ecogenomics were related to science, research and knowledge gain (e.g., “researching an area by looking at the gene expression of micro-organisms within that area”), its multidisciplinary character (e.g., “it is a mixture of biology, ecology and environmental sciences”), and its applicability (e.g., “researching micro-organisms that, through their influence on health and the environment, may enhance human life” and “ecogenomics researches our world at the molecular level, it is all about cleaning up, researching and enhancing nature”).

Perceptions on students’ information-seeking behaviors

SCIENTISTS. Most scientists thought the Internet, or, more specifically, websites would be the most likely information sources to be used by students when searching for new science information, but some also referred to more traditional mass media such as newspapers. Scientists indicated that they thought students would have difficulty searching for information about science in general and about ecogenomics in particular because of the vast amount of information available on the Internet. They indicated that this would make it difficult to search, retrieve and select information students would need to enhance their understanding. Some scientists also indicated that students should use information that is not always publicly available or popularized: “[…] they should use PubMed. But that is something you need to be able to access and use.” Most scientists did not think that students would come into contact with ecogenomics through the mass media. Rather, they indicated, that if students would be confronted with the issue then it would most likely be in an “in-school” setting. For example during biology classes (but this was considered only to be likely if ecogenomics became part of the formal biology curriculum), or while searching for information about studying biology at the university. Should students be confronted with ecogenomics in an “out-of-school” setting, most scientists thought newspapers and television were the most likely sources.

TEACHERS. All teachers mentioned that training students in their information-seeking behaviors was part of their education. Some mentioned that information seeking skills were taught in overarching classes but most indicated that such training was part of their own classes and assignments.
During biology and ANW [natural science classes] I will give students assignments that address this issue. For example, when searching information about Huygens, the website of the Huygens Lyceum will not provide any useful information. In the first year of school they are instructed on how to use search engines on the Internet, but students learn more from each other than they do during such classes.

Overall, most teachers consider this type of training important. For example, one indicated that it would be desirable to spend more time on it, but that there currently is a lack of proper teaching materials. Another problem this teacher indentified was that there generally is a lack of uniformity in how the skills are being taught. It was also noted that the training was dependent on the facilities available to them in school. Two teachers expressly indicated to have access to a multimedia centre and/or computer classroom in school and to find that important because students “learn by doing mostly.” According to the teachers, the students are not always positive about this type of training.

They find it [searching for information] difficult, but they are stubborn and do not learn much from assignments that require them to do it. They consider themselves well-able to do it already and this makes it difficult for them to accept that there are other means and methods that are also useful and perhaps better.

Other teachers provided similar examples, indicating that students find this type of training difficult, unnecessary and undesirable. According to them, students preferably prevent becoming involved in too elaborate information-seeking behaviors and are unselective in the information they use. An express example was students’ use of “Wikipedia.” Most teachers considered this website to be an unreliable source (in educational contexts) but acknowledged that most students make frequent use of it.

To make the training relevant for students, they should experience a direct benefit from it, as well as from the more elaborate search. However, the training may also serve a different purpose for the teachers. One teacher indicated that it showed to the students that teachers are also familiar with the Internet, know how to use it, and this, in turn, may deter students from misusing it (e.g., copy-pasting information). Not all teachers were negative about information-seeking training-assignments. Two indicated that their students enjoyed such tasks and that this “shows by the enthusiasm with which they set out to work” and that students “always enjoy using computers.”

According to teachers, students’ information-seeking behaviors are generally limited to their usage of the Internet. They expressly mentioned “Google” and “Wikipedia.”
The Internet was thought to be the preferred source because it is easy to use and provides students with illustrations. Additionally, they thought students might benefit from interactions with their peers. One teacher: “They are stimulated by others. They hear you can find a lot of information and this is confirmed through personal experiences.” However, students were thought to lack the skills to judge if information is reliable and trustworthy, in which case sharing of information might pose a problem.

At first they believe everything they can find. By providing feedback you hope to adjust their [information-seeking] behaviors. For them it is a process of trial and error, but for us as teachers it is as well.

An expressly noted difficulty in training students’ information-seeking behaviors was that students do not often provide references in their texts. This was thought to limit the possibility for teachers to evaluate and guide students’ behaviors.

STUDENTS. Most students indicated that their information-seeking behaviors were trained at school. Some mentioned formal lessons about seeking, retrieving and processing information. Others indicated that training consists of (informal) interactions with their teachers as part of a specific assignment. One student stated that she had missed this type of training, especially in relation to the Internet as an information source. Another indicated that such training had only occurred after he had personally asked his teacher about it.

Not all students considered this type of training important or useful. One expressly stated that it was a waste of time: “[…] most students in our class already know more about [working with] computers than what they [the teachers] are trying to teach us. It becomes somewhat redundant.”

All students indicated that the aspect of trustworthiness of information sources had been brought up during their education. In general, books, magazines and newspapers were considered to be trustworthy information sources. To illustrate:

[…] books are definitely trustworthy; especially when it has many pages and is on one subject because then the writer must have done a lot of research to have been able to write it.

[…] newspapers are trustworthy because they [indicating both the newspaper and the journalist] have a reputation to uphold, they will lose their subscribers if they publish bad info.
Students were less uniform in their opinions about the trustworthiness of the Internet. This opinion seemed to be predominantly based on students’ perspectives of how teachers evaluate the Internet as an information source rather than how they themselves evaluated the information retrieved from it.

Most were able to give an idea of how to evaluate the trustworthiness of information they retrieve from the Internet. In general, students considered “adds” to be an indication that information is not to be trusted and “errors in spelling, grammar and punctuation” were also mentioned to be used as an indication that the information was unreliable. Students were found to generally consider university and governmental websites trustworthy. Also, the use of scientific language (jargon) and factual information (numbers) were considered important indications of a source’s trustworthiness. Some students indicated that they compared information from different sources to judge its reliability and trustworthiness. One stated:

I generally look for various sources so you can compare the information. If it is similar than I consider it to be trustworthy. Articles in magazines are trustworthy and website of scientists too. Language is also important. Jargon makes it trustworthy.

When asked how they would search for information about ecogenomics, most students indicated that they would not become involved in elaborate searches. One student noted: “I would read a newspaper article about ecogenomics but I would not search for additional information.” Most students thought that they might become involved in more elaborate searches when ecogenomics would be discussed in class or when it was part of an assignment. Also, some indicated that they would probably search some information about it when ecogenomics became more “mainstream” and had received more attention in public media. The students indicated that when a subject was considered personally relevant or generally interesting they do search for information about it in their own time (e.g., “…we recently saw a documentary about soils that I found interesting, so I looked it up on the Internet”).

Societal relevance

SCIENTISTS. Most scientists thought that students would find ecogenomics interesting. Particularly the technological aspects (development of measurement instruments) and environmental aspects (cleaning of pollution) were considered interesting, but also the potential for agricultural use was mentioned. Some scientists indicated that students would only be interested in ecogenomics if they already were interested in biology in
general. Finally, some also indicated that the subject of ecogenomics was “far too technical” and “hardcore science” to be of interest for students.

To increase perceived societal relevance, scientists suggested that public media should provide examples to illustrate ecogenomics’ relevance and relate it to people’s everyday lives. However, they had difficulty in providing specific examples. One scientist indicated that the societal relevance was obvious and deeply embedded in the consortium’s research program and provided an example of attempts to establish dialogues between scientists, farmers, and companies.

*The entire discipline is anchored in its social component. That means we should initiate dialogues with society. We cannot just develop stuff because we like to.*

**TEACHERS.** Overall, most teachers thought that enhancing students’ understanding of science in general, including the issue of ecogenomics, was important. An increased understanding was thought to better enable students to see how the relevance of science of society and for students personally. Others indicated that it was relevant because this would enhance their intellectual development and better enable them to critically process new science information and that this type of information would be relevant for students to enable them to make better choices about a field of study or future careers.

*It is important for students to be able to evaluate and weigh public science information, to understand its implications, and to know how that knowledge came about.*

One teacher stated that the enhancement of students’ understanding of science was not relevant at all:

*If students do not go off to study science then why should they know this? I would be happy if they would read newspapers on regular basis.*

Most teachers did not think students perceived science in general or ecogenomics specifically to have much societal or personal relevancy. In example, one teacher noted “Only one-in-ten students is interested in science, the rest just likes games.” Another stated: “Only four or five students in my class read science magazines.”

The teachers themselves thought that (future) applications of ecogenomics illustrated the societal relevance of ecogenomics. However, some were found to struggle with questions about more fundamental aspects concerning the issue of ecogenomics (e.g., “is ecogenomics ecology?” and “is it biotechnology?”). The stage of development
of ecogenomics was also considered an important aspect of (social) relevance (e.g., “is it already in use?” and “are products available?”). Some teachers also indicated that possible risks might illustrate how scientific developments are relevant for society. One teacher suggested that students should ask themselves whether ecogenomics experts know enough about ecosystems to actively intervene and “do they understand the long-term effects of such actions?”

To increase students’ interest in ecogenomics, and to enhance the perceived societal relevance, teachers suggested that communication should focus on practical examples and actual applications of the technology. They suggested that the cleaning of pollution and the discovery of new medicines might be good angles to introduce the issue to students. One teacher also noted that when students had personal experience with ecogenomics-related problems the issue might be perceived as more relevant:

[… polluted soils are of every-day concern. Our school is located near an industrial site. There are students living in that area and to them it may very well have some personal relevance.

Overall, however, most teachers did not consider ecogenomics an interesting issue for students.

Bacteria are not really interesting for them, just as the environment and plants are not. Students are mostly interested in their own bodies.

STUDENTS. All students considered science in general to be of personal relevance and most indicated that they thought ecogenomics to be (or could become) personally relevant as well. Some were personally interested in the subject (e.g., “It sounds like ecogenomics is about figuring out how everything works and this is exactly what I want to know”), while others indicated that they considered the subject interesting in relation to personal decisions they would have to make (e.g., to be able to decide what to study after having finished school), and still others expressly stated that they thought other subjects to be more interesting and relevant (e.g., computers).

Most students did not think that ecogenomics would be of any direct influence on their personal lives at this time but that it might in the future, especially when ecogenomics would result in a clean environment or in the discovery of new medicines. Some example statements:

I find the environment important, so if soils can be cleaned using ecogenomics than it sounds as something useful in my life.
Certainly, when they discover new medicines or when ecogenomics can in fact clean up pollution [...] perhaps it will increase ‘the green’ in the Netherlands.

If ecogenomics includes water-purification and antibiotics then yes of course.

One student thought that ecogenomics would become personally relevant if friends turned out to choose it as a field of study. Another was found to be somewhat more skeptic about the relevance of ecogenomics:

[...] perhaps when they discover flesh eating oaks or something, but I do not see that happening any time soon.

It might be interesting to note that students were also found to consider information about the scientists to be of interest (and personally relevant). In interactions with scientists, students indicated that they would want to know more about scientists’ personal lives and reasons for pursuing a career in science (e.g., “What is your salary?” and “What do you like about being a scientist?”).

Value of direct interactivity

Scientists. Most scientists indicated to have no or little previous experiences with direct interactivity between themselves and teachers and/or (pre-university) students; in fact, most reported to have no experience even with (first year) university students. Nonetheless, most scientists considered themselves easy to approach and accessible.

We have no direct interaction with adolescents, but it shouldn’t be too hard for them to find my e-mail address or to call me. As a person, scientists are generally accessible.

Another indicated: “In general scientists are accessible. They have large egos, so if you give them an ego-boost they will be willing to participate.

But other scientists were less enthusiastic to participate and less optimistic about scientists’ accessibility for students. One indicated that he considered scientists to be accessible but that students should not expect to receive an immediate response. Another expressly noted:
You would like them to be but I doubt that they are. On public information
days at our university students might approach you but that contact is not
about the science or about the scientists. The language is also difficult [indica-
ting that he had difficulty to explain and/or simplify science to students].

Although all scientists thought that direct interactivity was important, not all of them
would be willing to have a role in it. One scientist explicitly stated that he would be un-
willing: “Rather not, I don’t have the time.” Additionally, most scientists seemed to ap-
proach interactivity from a sender-based perspective. To illustrate, some teachers men-
tioned that direct interactivity would enable them to provide students with up-to-date
and trustworthy information. Additionally, examples of direct interactivity with students
were “giving lectures at school” or “allow teachers free access to scientific symposiums
and conferences to keep them informed.”

When asked what media scientists would use for communication purposes,
most indicated that they would prefer (non-interactive) mass media, such as newspa-
papers and television. Some mentioned that, in the case of students as a target public, the
Internet might be better suited. Interestingly to note, schools were also expressly men-
tioned by some scientists as a potential medium, or, perhaps better put, environment in
which ecogenomics might be communicated. Some scientists suggested that they could
cooperate in the design of new teaching materials, facilitate exploratory internships, and
give lectures at schools. Three scientists expressly noted that such efforts should directly
contribute to the efforts to increase the enrolment in science and technology studies at
their university (and preferably lead to an increase in the number of PhD students in this
field of research).

Although this might seem indicative for scientists’ positive attitudes toward
direct interactivity, it is important to note that only two scientists were actually involved
in science communication. And in both cases the mode of communication was not very
interactive (writing a column for a newspaper and giving lectures for non-scientists).

TEACHERS. The teachers indicated to have no or little direct interactivities with scientists
but, obviously, a lot with students; those who had indicated that they were in direct
contact with scientists added that these were social contacts and generally not used for
professional purposes.

Teachers also suggested that guest lectures by scientists were a good way to
initiate direct interactivity between themselves and scientists and students. However, as
one indicated, teachers would need such guest lectures beforehand to be able to decide
whether or not a subject would be interesting enough for students as well as whether or
not it can be linked to the subjects that are part of the formal curriculum. Another suggested that scientist-teacher-student interactivity might be technologically facilitated:

*There should be a site for students on which headlines are published that refer to scientific developments. Quizzes are also fun, but these should be more in-depth for older students. The site should also allow students to ask questions to scientists and contain video materials.*

Three teachers expressly noted that direct interactions between scientists and students would be valuable, for example by having students interview scientists, but (other teachers) also indicated that, if direct interactions are too much of an effort, they would also welcome pre-designed materials that they might use in class. However, as one noted, such materials should preferably be directly linked to existing teaching materials (e.g., “to specific chapters in our book”).

According to teachers, for scientists-teacher-student interactions to be successful, all participants must be aware that it will encompass a time-consuming process and that for partaking scientists there are few benefits. They also indicated that scientists would need to change the way they currently communicate with students. According to them, scientists are predominantly trying to transfer information (“too much about too little”) and that they are used to writing science articles but not to interacting with adolescents.

*At guest lectures scientists present too much information. That is what they think it is about. Just about providing new information and not about getting the students to think.*

According to teachers, there is currently little direct interactivity between the three groups because scientists do not consider students to be an important target public. (And indeed, scientists had mentioned policy makers and potential consumers as their primary audiences.) Additionally, teachers thought that the preferred mode of communication among scientists is too different from that preferred among students. Teachers suggested that scientists should become more actively involved in the development of WebQuests, quizzes and videos, as well as in the organization of field trips and experiments for students. Teachers thought that students would enjoy direct interactivity with scientists and that any materials that are different from what is generally used in schools would be welcomed by students.
STUDENTS. In contrast to what scientists and teachers reported, students thought that those two groups were in direct contact on a regular basis.

*Teachers are, of course, still deeply embedded in the scientific world. They visit conferences and such. That is where they meet people, talk to scientists, and build their network of contacts.*

Most students indicated that they themselves did not know any scientists, but that they did consider themselves well-able to find them, should the need therefore arise. In this light, most students thought that scientists would be easily accessible. The students indicated that they expected scientists to be readily available at universities and hospitals, but they also thought that scientists who appear in public media would be easy to approach. For example, one pointed out that when scientists write for newspapers or magazines, he would probably be able to contact that scientist through the editors. However, only very few students were found to have had direct interactions with scientists for information seeking purposes. It is perhaps noteworthy that when students had become engaged in this mode of communication with scientists it was because of a school assignment rather than because of their personal interest in the subject or the person.

Despite its many affordances for high levels of interactivity, in relation to the Internet most students indicated to prefer content-oriented websites over interactivity-oriented websites in the context of communication about emergent technologies. In their initial search for information they desired a website that would provide them with background information (e.g., answers to the questions “What is it?” “What does it do?” and “What is it for?”). Furthermore, most students indicated to have a preference for audio and visual materials. One stated:

*I would show a video with someone explaining something about ecogenomics.*

*I would use lots of videos, animations and visual effects because these attract attention.*

Students also indicated that they would include a forum on the website, as well as a FAQ-page (Frequently Asked Questions) and some contact information. One indicated that a website should have a specific focus: “I would focus on the medical applications and medicines,” although later she added, “cleaning of pollution is also relevant today.” In contrast, other students indicated that a website should provide a complete overview of all the aspects of the research project. One stated: “I would describe all research aims.” In general, students find the structure and organization of the content very im-
important as well as a website’s navigational features. One stated: “It should be structured and organized; there should be links between issues and a title clearly presented at the top of each page.” One student also expressly noted that the use of scientific jargon was expected (and considered okay): “It should contain jargon, but not too cryptic. Especially in English the terms can be difficult.” Also, some students expressly stated what an ecogenomics-website should not contain: “It should describe what ecogenomics is and what progress has been made, but I wouldn’t present failed experiments” and “no advertisement.”

**Conclusion and discussion**

This qualitative exploration has shown that there is little direct interactivity between scientists, teachers and students at this time, but that all groups perceive it as potentially beneficial in the context of introducing ecogenomics to young people. The participants seemed to agree that full and direct interactivity may be unnecessary, but that lower levels of interactivity can be desirable. Overall, for those involved in this study, the focus was more on information transfer than on transaction – scientists predominantly see themselves in the traditional sender role, teachers are willing to take on a role as intermediates but are currently not interacting with scientists on a regular basis, and students themselves acknowledge that they are predominantly information consumers when communicating about emergent technology.

This study proposes that pre-university schools may be an ecosystem in which science communication can meet education in the context of introducing emergent technologies. Schools are better equipped to teach students information seeking skills and this type of training may be expected to better enable them (as future adults) to search, retrieve and process new science information; especially skills enabling students to cope with (technological) changes in (mass) media affording for different levels of interactivity. In this light, it is important to conclude that teachers considered this type of training well-embedded in the formal curriculum, but most students did not. And although most students considered themselves well-able to search, retrieve and process new science information, most teachers thought students generally performed non-elaborate searches and often used untrustworthy information sources.

Communicating about emergent technologies to students in school settings may be expected to produce most of the personal responses indicated by Burns and colleagues (2003). In example, scientists and teachers had high hopes that it would increase awareness among students. Teachers indicated that students enjoyed information seeking and interactive tasks especially when the content deviated from the existing teaching materials. Students were found to be interested in emergent technologies in
general. In the case of ecogenomics specifically, students indicated to find the potential discovery of new medicines and the cleaning of pollution most interesting. Scientists and teachers also indicated that new information about emergent technologies might increase students’ interest in science in general. Simply introducing emergent technologies in school, however, need not result in enhanced understanding among students. Scientists and teachers perceived students’ cognitive engagement as low and especially teachers pointed out that students do not generally set out to attain elaborate understanding.

Secondary schools may be considered to be an interesting environment for science communication professionals (and education at the pre-university levels specifically). Although the interviews showed that the three groups perceive many difficulties in attaining high levels of interactivity, the process may benefit from an active and independent moderator. This moderator should aim to create an environment that enables direct interactivity between the three groups but needs to acknowledge the barriers raised by the interviewees. Most arguments for potential barriers were raised by the scientists. These barriers seem similar to those raised in scientist-journalist interactions (as described by Peters, 1995; 2005; Willems, 1976; 1998; Valenti, 1999). However, by changing from mass media to schools, and from journalists to teachers, some of these barriers may be overcome: There will be more time available for the different participants in the process (less strict deadlines); scientists may retain more control over content than they do in scientist-journalist interactions (especially if he or she is willing to actively participate in the co-construction of materials); the goals and purposes of the participants may be expected to be more similar; and teachers may be expected to have a similar background as scientists do which might limit the barriers raised due to professional and cultural differences. For science communication professionals as moderators of this process, the aim is to create an environment in which scientists, teachers and students may interact directly in such a manner that it does not cost too much time (for scientists in particular), the information exchange is related to the formal educational program (for teachers in particular), and the societal and personal relevance of the issue is obvious (for students in particular).

Although teachers expected scientists to take on an active role in information transaction, they emphasized that it is not necessary for them to design materials with an educational purpose in mind. Most teachers considered themselves well-able to adapt the materials scientists might provide accordingly, but unable to retain the required information themselves. Using emergent technologies as exemplar cases, most teachers thought to be able to enhance the perceived societal relevance of science for students. Students also indicated that such cases might be interesting, focusing particularly on examples of how science and technology is applied in everyday life.
The Internet was suggested as the most viable medium through which to communicate ecogenomics. It was praised for its vast amounts of information, capabilities to let students search for information, and the fact that it provides up-to-date information about scientific developments. It was predominantly criticized by teachers for the risk of exposing students to unreliable or irrelevant information. However, what is currently lacking is an information environment that teachers can use in their classes providing students with trustworthy information but still requires, or, perhaps better put, allows them to perform certain information seeking and processing behaviors, including the means to interact directly with scientists, teachers and other students for example by asking questions and sharing experiences.

This study also has limitations. First, the purposive sample used in this study was small and generalizations about its results should be made with some caution. Second, we chose the issue of ecogenomics specifically because it was an emergent technology and was generally unknown among teachers and students. However, a drawback may have been that this unfamiliarity with the subject has influenced participants’ perceptions of societal and personal relevance (hence the difference in perspectives of scientists versus teachers and students). These perspectives may be expected to change when actual applications of ecogenomics are introduced in society. Additionally, in the interviews, some of the participants indicated that ecogenomics may not be the best suited emergent technology to initiate and maintain interactivity between the three groups. This was predominantly because the issue was not expected to be considered personally relevant by students and because it was too distant from its related subjects in biology as they are taught in school. Third, students in our sample were aged between 15 and 18. This sample was selected because teachers suggested that these students could be expected to be better able to make use of existing knowledge of biology to make sense of the new information about ecogenomics. Additionally, students of these ages were expected to be better able to put their opinions and perspectives on the various concepts into words than students of younger ages. However, the results indicate that a younger age category might also be interesting, because the students in this sample indicated to find themselves well-able to search, retrieve and process new science information. This might be interpreted that their information-seeking behaviors are already set. Future research may want to investigate at which stage in their educational program, or at what age, students are still developing these behaviors and, perhaps more importantly, if these behaviors can be influenced and changed.

More qualitative research on students’ perspectives on science and emergent technologies is important, particularly in the Netherlands where the numbers of students that enroll in science studies at a university are dwindling (The Dutch Ministry of Education, Culture and Science, 2009). In this light, students are especially interesting
as a target public for science communication because the enthusiasm for the natural sciences that is present among young children seems to diminish in later life (as suggested by Hoorn and Walma van der Molen, 2007). Since students are forced to make important choices about their future at early stages in life – students have to choose an educational profile at the age of 14 to 15 differentiating between beta- versus social-sciences oriented profiles – these types of qualitative investigations may provide more insight into why students do not choose to study beta-sciences, as well as provide handholds on how they want to participate in science communication processes.
The studies