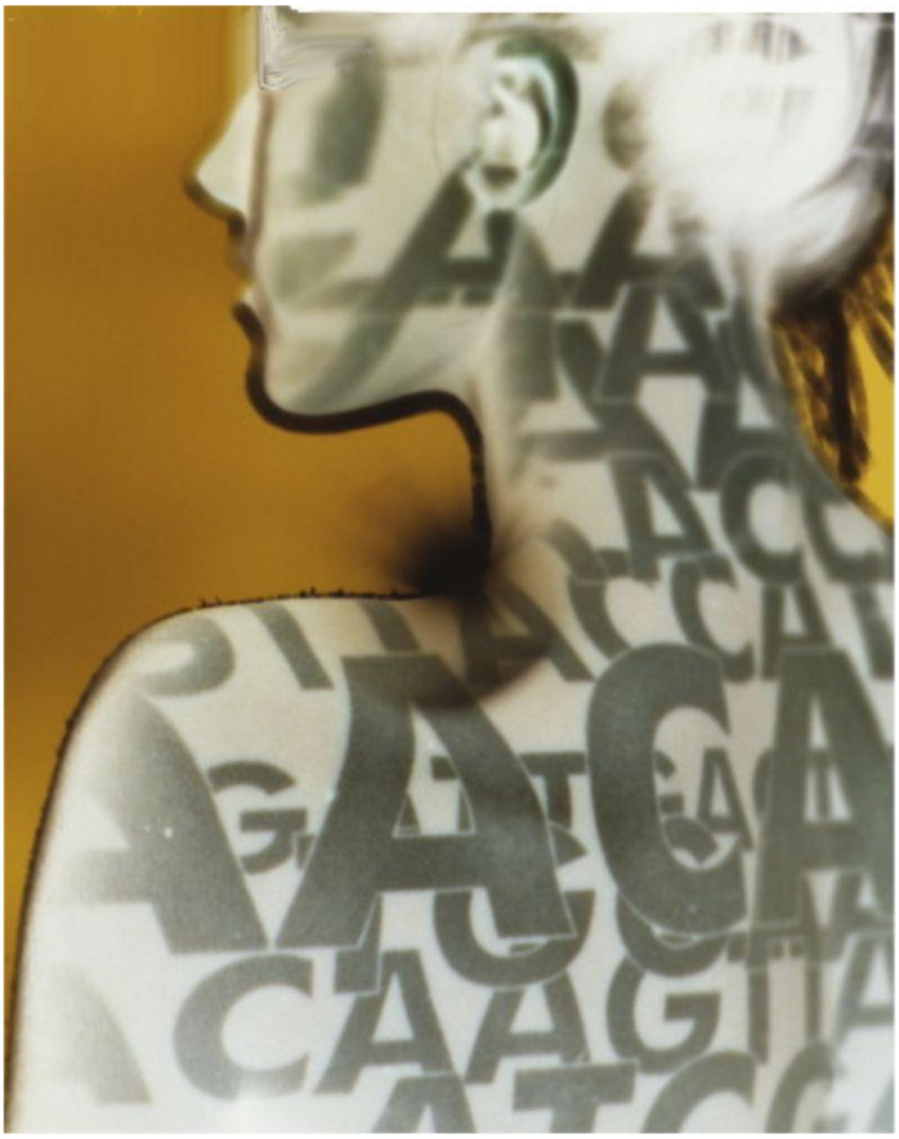
The meaning secondary school students attribute to genome metaphors



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Abstract

The meaning secondary school students attribute to genome metaphors, the blueprint and recipe metaphor especially, was studied by conducting a quantitative survey among 148 students from upper secondary education. This quantitative study consists of a questionnaire and semantic a scale.
Most students that participated in this study think about their genome during biology class (39%) and a great majority of students (77%) mention that they acquired their genomic image from school. Almost three quarters of the students think about genomic structure immediately after thinking about the genome. This could mean that high school education focus on genomic structure.
When students have to choose between the recipe and blueprint metaphor, a majority (57%) preferred the blueprint metaphor. They perceived this metaphor as less variable, more fixed, more determined, more static and less active than they perceived the recipe metaphor. This deterministic view is consistent with the expectations of proponents of the recipe metaphor, who state that the blueprint metaphor emphasizes a deterministic genomic image by comparing the genome with a design that only has to be executed (Condit *et al*, 2002; Condit, 2004). The blueprint metaphor was declined, because it was perceived as too fixed, too uniform and unnatural.
The students that evaluate the recipe metaphor as more suiting (11%) describe this metaphor as more complete, variable and original. This metaphor was also closer associated to small, personal, simple, friendly and change. On average, the students rate the recipe metaphor as less deterministic than the blueprint metaphor. This is consistent with the expectations of experts (Rothman *et al*, 1998; Hubbard and Wald, 1993; Condit & Condit, 2001). The students decline the recipe metaphor because of its randomness and simplicity.
The deterministic view of students was also highlighted by the genome metaphors of the students. 65% named a deterministic genome metaphor, like a code, book/database, switch panel, manual or design. 14% named a materialistic genome metaphor, but perceived this metaphor as rather deterministic also.
The remaining students produced a building bricks (13%) or community (8%) metaphor. Both metaphors were rated less deterministic and freer by the students.
An emphasis on Mendelian genetics and human interference in Dutch genomic education could cause this deterministic genomic view among students. This could be corrected when genomic educators emphasize more on gene-environment interaction and epigenetics when using either metaphor. Education could counterbalance determinism by using an appropriate combination of metaphors.

Inhoud

Introduction

In the near future, people will increasingly be asked to undergo genetic testing for a variety of medical purposes. A central example is the rise of prenatal genetic testing practices in the past half century, which often delivers parents not only information and advice but also moral and ethical dilemmas. In the future, genetic tests will also be used for diagnosis of predisposition to disease and to individualize the use of drugs and medical treatment. Citizens will need increased understanding of genomics to make informed choices when they come into contact with it. A correct image of the genome could support a well-considered decision. Next to this, the genomic image of the public is also crucial in public opinion. The importance of public opinion on scientific issues is highlighted by the dispute over genetically modified crops and debates about the use of human embryonic stem cells in research.
However, several studies have shown that the lay person has a lot of difficulties understanding different aspects of genetics. People do for example not understand what genetic testing actually is or how they should interpret the results (Condit *et al,* 2010). Also, a better understanding of science could lead to more rational debates and outcomes. Therefore, it is important to educate and communicate about genetics to the public in an understandable manner. Most people get their first (and last) knowledge about genomics on high school, so this is an important place to optimize genomic education.

One major tool for explaining genomics, both in science-education as in science-communication, are metaphors. Metaphors can be defined as imagery based on a comparison. Linguistic Lakoff and philosopher Jonhson (1980) state that metaphors are common ways of representing reality:

> "Since much of our social reality is understood in metaphorical terms, […] metaphor plays a very significant role in determining what is real for us."

They help to explain and popularize complex scientific information and suggest social meaning to the public. Studies show that metaphors play a crucial role in both the thinking- and concept-making-process (Condit & Condit, 2001). Also, it has been proven that metaphors have a great influence in understanding biological concepts (Konopka, 2002).

Although metaphors seem like a perfect way to communicate and educate genetics, they have an important limitation. Metaphors have a risk to be confounded with the real thing. Metaphors connect two conceptual domains: the target domain and the source domain (Lakoff and Johnson, 1980).The source domain is the conceptual domain from which we draw metaphorical expressions. The target domain is the conceptual domain we try to understand. For example, in the metaphor "*love is like a journey*", "*love"* is the target domain and "*journey"* is the source domain. These domains have common characteristics which are used in the comparison, as well as differences. In genome metaphors however, it is not always clear which parts of the source domains can or cannot be used to understand the target domain. This makes it easy to misunderstand genome metaphors. Also, a metaphor can restrict horizons when characteristics of the target domain that have no parallel in the source domain are neglected. The metaphor of the genome as a finely tuned machine may blind to genomic imperfections caused by phylogenetic constraints or evolutionary-genetic trade-offs (Avise *et al*, 2001).
Therefore, it is important to search for the most suitable metaphors of the genome. Two genome metaphors often used nowadays are the blueprint and the recipe metaphor. Condit *et al* (2002) explored how potential members of the public might understand the recipe and blueprint metaphors and found a difference in interpretation between lay people and popular science writers. This difference in interpretation could result in misunderstandings of misconceptions among lay people.

The same difference in interpretation of genome metaphors might exist between students and teachers/textbooks and could lead to misunderstanding and misconceptions among students. To

optimize the communication between science educators and students, it is important to learn more about the meaning students contribute to existing metaphors as the blueprint and the recipe and to other genome metaphors they use themselves. Therefore, the aim of this research is to find out which meaning secondary school students attribute to the blueprint and recipe metaphors in relation to the genome and hereby learn more about the genomic image of the students. The main question of this study will therefore be:

"Which meaning do secondary school students attribute to genome metaphors?"

To answer this question, this study will deal with the following sub questions:
1) Which meaning do secondary school students attribute to the genome in general? Where is this genomic image coming from?
2) Which meaning and values do secondary school students attribute to the recipe and blueprint metaphors?
3) Does the meaning secondary school students attribute to the recipe and blueprint metaphors fit with the meaning of the experts?
4) Which other metaphors do students use in describing the genome? Which meaning and values do secondary school students attribute to these metaphors?

The results of this research will inform education on which genome metaphors are suitable for upper secondary education. This knowledge may contribute to reflection on genomic education for both teachers and writers of educational material.

Literature study

The rise of scientific metaphors

Natural science educators did believe for a long time that metaphors are incompatible with true science. The Greek philosopher Aristotle stated that metaphors are not identical to the truth. Muscari*et al*(1988) supported this view by stating that metaphors offer too much freedom in interpretation. Despite this, the scientific world acknowledged science did not had to be based only on direct observations (Muscari, 1988). Consequently, metaphors became a valuable tool in explaining abstract biological concepts.
Linguistic Lakoff and philosopher Jonhson (1980) state that the essence of metaphor is understanding and experiencing one thing in terms of another. Metaphors originated as resource to convince others (Konopka, 2002). Nowadays, metaphors function in explaining and bonding different concepts (Avise, 2001). Using metaphors can stimulate the learning process by explaining abstract ideas and increase thinking at higher levels (Aubusson*et al*, 2006) and metaphors help understand complex concepts (Muscari, 1988; Duit, 1991). Ortony (1975) has three arguments why metaphors are functional in education. First, metaphors can tell more in fewer words. Second, metaphors are a way to tell something when there are no proper words. Third, metaphors are closely related to the imagination, because they are lively and easy to visualize. Therefore, metaphors can also help popularize complex scientific information and suggest social meaning to the public (Nelkin, 2001).
It has been proven that metaphors have a great influence in understanding biological concepts (Konopka, 2002). Due to this, metaphors are frequently used by science educators and communicators nowadays.

Categorization of genome metaphors

Biological metaphors can be classified into three themes; machine, language and organic system metaphors. Genome metaphors can be classified in the machine and language theme.
The machine theme dates from 1637, in which the cell was compared to a little machine. Genome metaphors stemming from this theme are blueprint and database. A disadvantage of this theme is that machines do not have a past. Many genome metaphors fit into the language theme. The origin of this theme is unknown, but it arose somewhere at the beginning of genetics. The idea generated that every organism has its own body plan with a description of growth and development. The genetic information consists out of four nucleotides, adenine, thymine, cytosine and guanine, abbreviated to A, T, C and G. This is easily compared to a code or a text. A disadvantage of this theme is that the interaction between the cell and the genome implies more than just reading the genetic code.
Despite these disadvantages, the metaphors of these themes could still be useful in education (Konopka, 2002). Campbell and Reece (Biology, 8th edition, page 9) use the language theme when writing:

> "The entire "library" of genetic instructions that an organism inherits is called its genome. […] If the one-letter symbols for these nucleotides were written in letters the size of those you are now reading, the genetic text would fill about 600 books the size of this one."

Carver *et al* (2008) were able to define five distinctive main frames of communicating the gene concept by analyzing newspaper articles. The five main gene frames Carver *et al* have designed are materialistic, deterministic, relativistic, evolutionary and symbolic. Table 1 defines these five gene frames. To make sense of (scientific) knowledge, the information conveyed has to be organized into a larger, intellectual framework (Goffman, 1974; Gamson & Modigliani, 1989; Nisbet & Mooney, 2007). Science communicators and educators consciously or unconsciously frame their stories by using certain words, facts, depictions, images and metaphors. This way, scientific concepts might be presented or described in ways that communicate different meanings. For example, the genome can be described as "double-

stranded helices, consisting of nucleotides" and as "the blueprint for life". Both frames convey a different interpretation of the same reality. This can cause a different mental response in the reader (Kitzinger, 2007). The first description from our example describes the gene as a physical entity defined by a particular fragment or sequence of the DNA molecule. This is a materialistic frame and is sometimes emphasized by metaphors describing the genome as a code, book or map to be deciphered or read. The second description can be classified into a deterministic frame. This frame describes the gene as a deterministic entity that has the power to define identity, determine human affairs, dictate human relationships and explain social problems (Nelkin & Lindee, 1995). Metaphors describing the genome as computer program or instruction manual sometimes emphasize this frame. The frames of Carver *et al* were used in order to categorize the students' genome metaphors.

Table 1: Five gene frames according to Carver *et al* (2008)

Gene frame	*Subframe*	*Description of the gene*	*Key words and phrases*	*Metaphors*
Materialistic	–	A discrete physical unit	DNA, chromosome, identify, locate, isolate, deliver, transfer, specific, replace, inject, discover, code, protein, mutation	Alphabet, book, map, code
Deterministic	Classic	A definite causal agent	Gene for, cause, control, culprit, blame, disease-gene, responsible for, wired in genes, born with	Computer program, recipe/instruction manual
	Gene versus environment	Contrary to environmental factors	Genes or environment, not down to our genes, genetic, environmental	–
Relativistic	–	A predisposing factor	Risk, chance, factor, associated with, susceptible to, linked to, contribute, predispose, interfere, influence, play a part in, genes are involved	–
Evolutionary	Unit of selection	The central object of evolution	Being selected, make copies, replicate, reproduce, through generations, adapt, maladaptive	The selfish gene
	Historical	A marker for evolutionary stage	Evolve, evolutionary relatedness, conserve, diversity, development, DNA record, gene bank, marker, extinction, change	–
	Interactive	Interacting with the environment	Interact, complexity, dynamic, capacity, external influence, environment, depends on, in combination with, affected by, expression, triggered by, prevent, respond, turn on/off	Like a switch or tap
Symbolic	Rhetorical	An abstract representation of inheritance	It must be in the genes, good genes, gene pool, inherit, talent, "I inherited a shopping gene"	–
	Metaphoric	A metaphor for information transfer	For example, Mazda got "Ford genes"	–

Critics of genome metaphors

Several studies emphasize the tendency of the mass media to present genes as deterministic causes of human behavior or disease (Hubbard & Wald, 1993; Nelkin & Lindee; 1995; Condit *et al*, 1998; Conrad, 2001; Condit, 2007).

Different experts criticize the blueprint metaphor, by stating it emphasizes a deterministic genomic image by comparing the genome with a design that only has to be executed (Condit *et al*, 2002; Condit, 2004). The existence of genome metaphors is related to certain social factors. Nowadays, we talk about "violence genes" or "alcohol genes", which suggest people and human nature are pure products of their genes (Nelkin, 2001). The blueprint metaphor has its origins in the quest to explain the cause for social problems, like violence or alcohol abuse. Hubbard and Wald (1993) state that the blueprint metaphor suggests that genes are like a control center that drives the organism. This is an incorrect image, because genes react to environmental influences to produce a functioning organism.

Many critics have a preference for the recipe metaphor nowadays (Condit & Condit, 2002). In this metaphor, the DNA acts like a passive cookbook. The genes and environment are the ingredients, which can be used actively by the cell (the cook) to form the phenotype (Hubbard and Wald, 1993). This metaphor is said to be less deterministic and more adaptable, flexible and variable. Rothman (1998) agrees the recipe metaphor has individual diversity and variability built in it. Also, the result is dependent of the different ingredients and proceedings (Rothman, 1998).

Other researchers think the recipe metaphor differs only marginally from the blueprint metaphor in terms of determinism, variability and temporality (Condit & Condit, 2001). Obviously, there is a lot of discussion about the different genome metaphors and every expert has its preference. To improve genomic education and communication however, it is important to learn how the public understands different genome metaphors.

Interpretation of genome metaphors

People have their own cognitive and affective knowledge. How somebody understands a certain metaphor depends on this knowledge (Abusson*et al*, 2006). This way, every person could have its own meaning attributed to a certain metaphor. Condit *et al* (2002) explored how potential members of the public might understand the recipe and blueprint metaphors by audience studies using a semantic scale, an interview study and student group talks. They also studied the use of the blueprint and recipe metaphor in the news. They found lay people did not attribute the same meaning to the genome metaphors as the critics did. For example, the public did not understand the blueprint metaphor as more deterministic or life-determined as the recipe metaphor. This difference in interpretation could result in misunderstandings of misconceptions among lay people. With this knowledge, researchers start to determine public understanding of genomics and how to improve this via mass communication, like newspapers (Carver *et al*, 2008; Condit, 2007). However, public understanding of genomics is mostly generated at high school. Therefore, it is important to learn more about the meaning secondary school students attribute to genome metaphors.

Methods

In order to explore which meaning secondary school students attribute to genome metaphors, a quantitative survey of high school students is performed. This quantitative study consists of a questionnaire and a semantic scale. Both were piloted among eight students from 5 VWO. Unclear questions, sentences or instructions were improved. The final version of the questionnaire and semantic scale are attached (attachment I). This final inquiry form was conducted among 148 students from 5 VWO in seven different schools: Marnix College (Ede, Christian), CSG Dingstede (Meppel, Christian), Koningin Wilhelmina College (Culemborg, Christian), Scholen gemeenschap Reigersbos (Amsterdam, public), Porta Mosana College (Maastricht, public), Carmel College Salland (Raalte, Christian) and CSG Farelcollege (Amersfoort, Christian). To assure a representative outcome, geographic, social and religious variety was taken into account.

Target group

The target group of this study was students in the eleventh grade of pre-university education which were following a biology course. The themes heredity and genes were taught a year before so these students had already some basic knowledge about the genome.

Questionnaire

The study of Annelotte Lammers (2010) is used to design the questionnaire. In this study, the genomic image of six secondary school students was studied through one-to-one interviews. These in depth interviews were used in the designing of the questionnaires. Useful interview questions were converted in the following five questionnaire questions:

> *Question 1: When do you think about your genome/genes/DNA and about what do you think?*
> *Question 2: Which image comes to mind immediately after thinking about the genome?*
> *Question 3: Where does your genomic image come from?*
> This is a multiple choice question, in which possible answers were 'school: biology class, teacher, books, pictures', 'home: family, friends, acquaintance', 'media: documentary, newspaper, news, television, magazines' and 'other, namely…'.
> *Question 4: Which of both genome metaphors (blueprint and recipe) is best suiting? Describe for both metaphors why you think they do or do not suit.*
> *Question 5: When you cannot use the blueprint or recipe metaphor, how would you describe the genome? Describe your own genome metaphor and why you think this is a good comparison.*

Semantic scale

A semantic scale was added to the survey based on the scale used by Condit *et al* (2002) to further explore how secondary school students might understand the recipe and blueprint metaphors. Next to this, the difference in the meaning and value secondary school students attribute to the recipe and blueprint metaphors can be studied. Complementary, the outcome of this can be compared to the opinion of the experts, extracted form literature.
The students were given a series of semantic scales. Question 6 asks the students to answer the semantic scale for 'the genome is like a blueprint' ('het genoom is als een blauwdruk'), and the 'genome is like a recipe' ('het genoom is als een recept'). Question 7 asks the students to answer the semantic scale for their own genome from question 5.

The connotative pairs tested came from Condit *et al* (2002) and were translated as follows: small/large (groot/klein), variable/uniform (variabel/uniform), personal/industrial (persoonlijk/industrieel), malleable/fixed (veranderbaar/vast), good/bad (goed/slecht), complex/simple (complex/simpel), I use/others use (ik gebruik het/anderen gebruiken het), free/determined (vrij/bepaald), friendly/threatening (vriendelijk/dreigend), change/static (groei/stilstand), I'm active/I'm passive (actief/passief), familiar/unfamiliar (bekend/onbekend), unique/universal (uniek/universeel) and growth/halt (groei/stilstand). Nurturing/controlling, female/male and growth/production were not used during this study, because the students from the pilot study did not understand these terms in relation to the genome. In order to determine whether a certain metaphor was rated deterministic by the students, the connotative pairs 'variable/uniform', 'malleable/fixed', 'free/determined' and 'change/static' were closely studied for each metaphor.
The students were asked to check the blank on the scale that represents how close the shade of the meaning of the word is to either the word on the left or the word on the right. These checks were converted into numbers, in which 1 represented the most left and 5 represented the most right blank. This way, differences in perceptions between the metaphors could be determined by statistically analyzing the semantic scales. The mean and standard deviation were calculated. Next, a two-tailed student T-test was performed to determine significance in differences between the blueprint and the recipe metaphor. A probability (p-value) smaller than 0,05 is statistically significant. This was not done for the students' metaphors, because there was a great variation between the different groups.

Interpretations

The research questions were answered in the following manner:

1) Which meaning do secondary school students attribute to the genome in general? Where is this genomic image coming from?
The answers to question 1, 2 and 3 were taken together to learn more about the genomic image of the students. These answers clarified were the genomic image of students is coming from, when students think about their genome and what students relate to their genome.
These questions together could tell more about the daily life meaning and the value students subscribe to the genome.

2) Which meaning and values do secondary school students attribute to the recipe and blueprint metaphors?
Question 4 and 6 are designed to find out which meaning and values students attribute to both genome metaphors. Students will have to tell why they think a metaphor is suitable (or not) and they have to fill in the semantic scale for both metaphors.

3) Does the meaning secondary school students attribute to the recipe and blueprint metaphors fit with the meaning of the experts?
Question 4 and 6 are designed to learn more about the meaning secondary school students attribute to the genome metaphors. The result of question 4 was compared to the semantic scales in question 6, in order to get a detailed picture on the view of the students about the blueprint and recipe metaphor. This is compared to the opinion of the experts, which were investigated by studying literature.

4) Which other metaphors do students use in describing the genome? Which meaning and values do secondary school students attribute to these metaphors?
Question 2, 5 and 7 are designed to find out which other metaphors students use in describing the genome. Question 2 could tell something about the existing genome images of students. Question 5 is designed to find out which other metaphors students use in describing the genome and indirectly again about their genome image. Categorization of students' genome metaphors was done by given explicit

definitions, examples, themes and student-quotes were designed or used for each category, in order to investigate the genome metaphors. This way, it is determined exactly under what circumstances a text passage can be coded with a category and a category agenda is made (Mayring, 2002). The five main gene frames from Carver *et al* (2008) were also used in analyzing the genome metaphors of the students. However, these gene frames are designed by analyzing newspaper articles. In this study, students were analyzed. In order to determine more precisely whether a certain metaphor could be categorized in a certain frame, the connotative pairs 'variable/uniform', 'malleable/fixed', 'free/determined' and 'change/static' were closely studied for each metaphor.
Interrelated reliability about the categorization of the metaphors is ensured by a second categorization by another researcher which produced the same categorization for 100% of the quotes.
The result of question 5 was compared to the semantic scales in question 7, in order to get a detailed picture on the genome metaphors that the students produce. The meaning and values of these metaphors were ascertained by the semantic scales in question 7.

Results

Questionnaire

Question 1

The majority of the students (39%) thinks about their genome during biology class (figure 1). 20 percent of these students thinks about heredity and 9 percent thinks about the different traits used in examples during the explanation. The rest did not mention what they think exactly. 24% percent of the students think about their genome when they think about the heredity of traits in their own family. The heredity of diseases is reason to think about their genome for 6% of the students. 5% percent answered they think about their genome when thinking about (their) traits in general. When thinking about future offspring 3% of the students think about their genome. 18% of the students state that they never think about their own genome. The remaining 5% mention they think about their genome when studying the structure or by different media, like documentaries and the television series CSI. They are referred to as 'other' in figure 1.

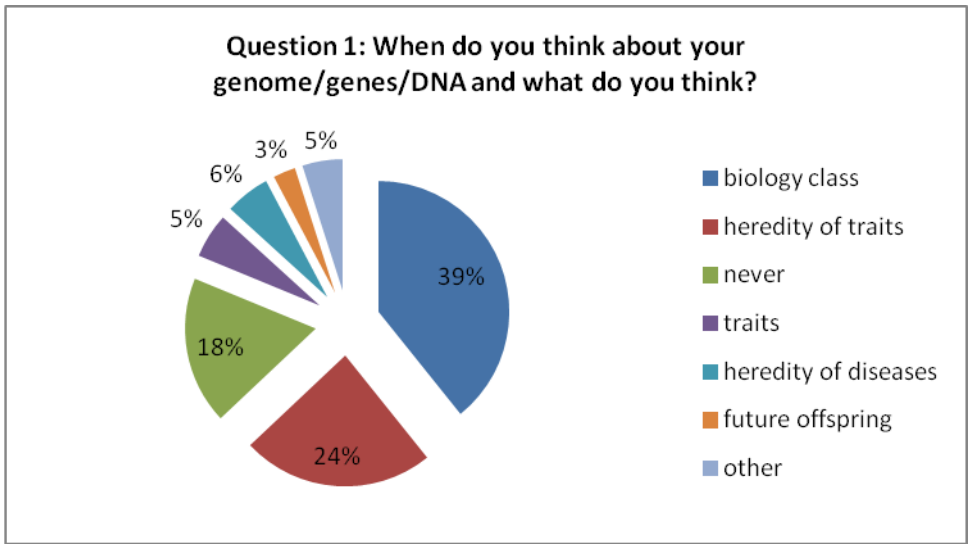

Figure 1: Pie chart showing outcome of question 1: When do you think about your genome/genes/DNA and what do you think?

Question 2

Question 2 asks the students which image comes to mind immediately after thinking about the genome. Most students (74%) think about DNA structure when they think about the genome. They name terms as DNA strands, chromosomes, DNA, double helix and genes. 19% of the students think about heredity. Mentioned in this category is heredity of phonotypical traits, heredity of disease, heredity in general and karyotype. 6 percent of the students think about a certain metaphor immediately after thinking about the genome. These students name images as a bookcase, spiral staircase, blueprint, puzzle and switch panel.
The percentages of students identifying certain images and the subdivision of the categories are represented in figure 2 and table 2.

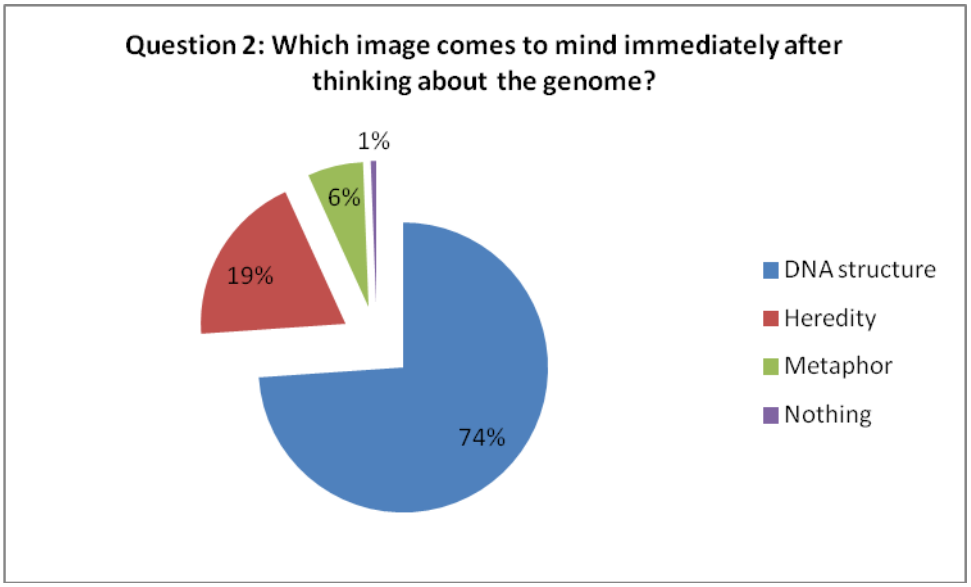

Figure 2: Pie chart showing outcome of question 2: Which image comes to mind immediately after thinking about the genome?

Table 2: Subdivision of categories

DNA structure (74%)		***Metaphor/image (6%)***		***Heredity (19%)***	
Example	*Percentage*	*Example*	*Percentage*	*Example*	*Percentage*
DNA strands	28%	Bookcase	29%	Phenotypical traits	53%
Chromosomes	22%	Spiral staircase	29%	Heredity	23%
DNA	21%	Blueprint	14%	Diseases	15%
Double helix	18%	Puzzle	14%	Karyotype	9%
Genes	8%	Switch panel	14%		
Other	3%				

Question 3

Question 3 asks the students where their genomic image came from. A majority of the students (77%) stated their genomic image comes from school (figure 3). 14% got their genomic image from media, like documentaries, newspapers, news, television and magazines. 6% of the students answered home contributed most to their genomic image. Of the 3% that answered 'other', the most mentioned scientific papers.

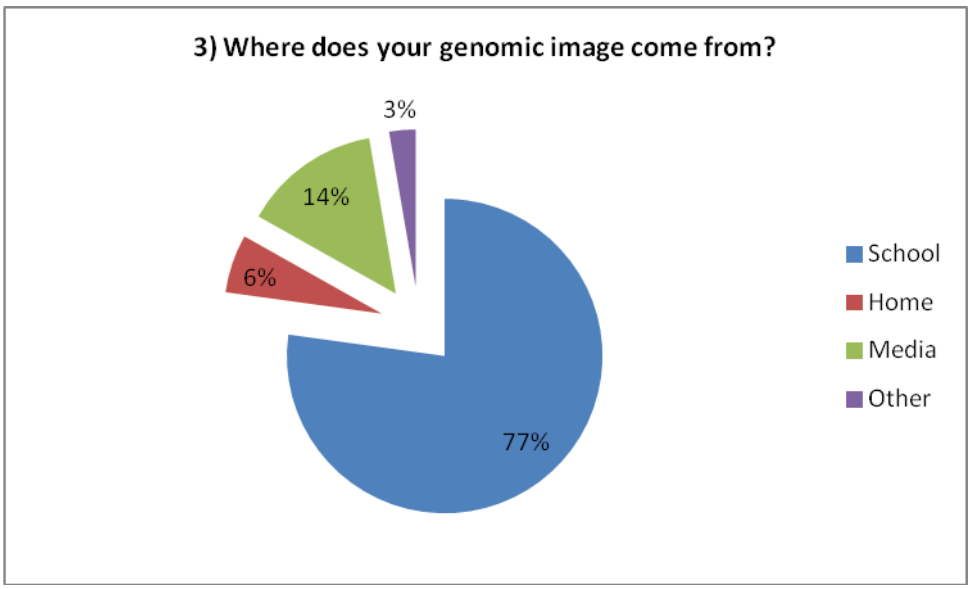

Figure 3: Pie chart showing where the genomic image of the students is coming from.

Question 4

Question 4 is designed to learn why students think the recipe and blueprint metaphors are suiting or not. Most students (81%) thinks the blueprint metaphor is suiting and (57%) thinks the blueprint metaphor is best suiting (see figure 4), because it is complete (53%) and detailed (25%) (see table 3). The recipe metaphor is considered less suiting. 33% of the students think this metaphor is suiting and only 11% thinks it is best suiting. These students mention its completeness (68%) and variability (28%) (see table 5). Opponents of the recipe metaphor state this metaphor is too random (36%) and simple (13%) (see table 6). The blueprint metaphor was rejected because it is too fixed (29%) (see table 4).

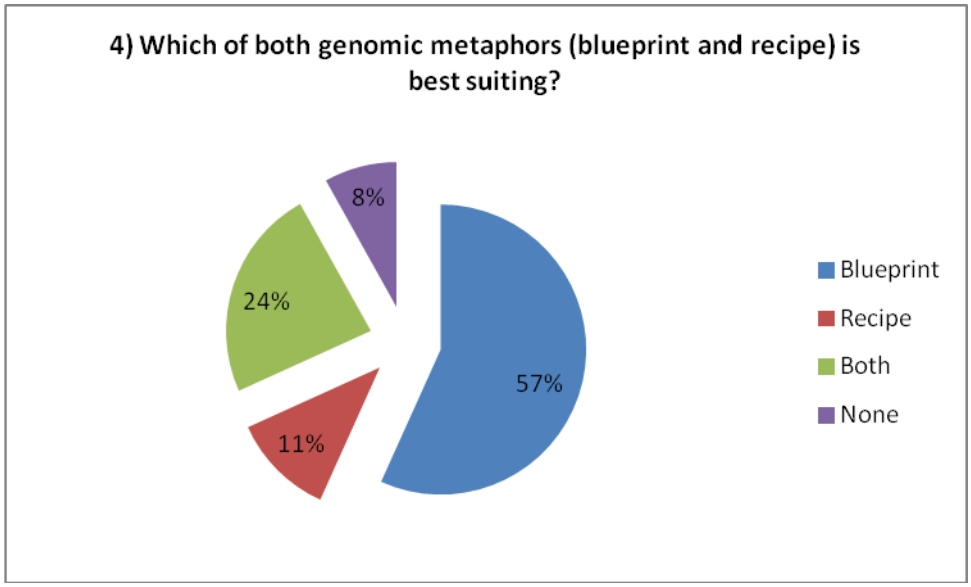

Figure 4: Pie chart showing percentage of students that have a preference for the blueprint metaphor, the recipe metaphor, either metaphors or no metaphor.

Table 3: Blueprint metaphor suiting		
The blueprint metaphor is suiting, because …	***Percentage****	***Quotes***
…it is complete	53%	"it is a total overview of how something is build."
…it is detailed	25%	"your genome tells in great detail how to build a person"
… the genome tells the body what to do	4%	"every cell in your body knows what to do thanks to the DNA, just like construction workers know how to build thanks to the blueprint."
…the body is built from pieces	4%	"a building is built from pieces, just like the body."
…it is fixed	3%	"the genome contains a fixed blueprint for the body."
…it sounds better	3%	"blueprint sounds more professional."
…it is well-arranged	3%	"you can easily see how everything is built up."
…it is variable	2%	"no building is the same."
Other	3%	N.A.

*Percentage of students that assess the blueprint metaphor as suiting.

Table 4: Blueprint metaphor not suiting		
The blueprint metaphor is not suiting, because …	***Percentage****	***Quotes***
…it is too fixed	29%	"everything is determined in advance and has to be executed this way exactly in order to function in the right manner"
…I see no comparison	19%	"I see no comparison"
…it is unnatural	14%	"blueprint does not sound natural." "a building contains unnatural materials."
…it is not detailed enough	10%	"a blueprint only describes the appearance."
…it is too uniform	9%	"one design for all people does not exist"
Other	19%	N.A.

*Percentage of students that assess the blueprint metaphor as not suiting.

Table 5: Recipe metaphor suiting		
The recipe metaphor is suiting, because …	***Percentage****	***Quotes***
…it is complete	68%	"the genes are the ingredients for proteins."
…it contains variability	28%	"[…] the dish can taste different every time."
…it contains the mixing of DNA	2%	"the ingredients (genes) of both parents are mixed."
Other	2%	N.A.

*Percentage of students that assess the recipe metaphor as suiting.

Table 6: Recipe metaphor not suiting		
The recipe metaphor is not suiting, because …	***Percentage****	***Quotes***
…it is too random	36%	"your genome is not just a soup with randomly chosen ingredients, it exists thanks to inheritance."
…it is too simple	13%	"when you simply throw all the ingredients together, you will not get a human body."
…the genome does not follow an action plan	12%	"you keep adding ingredients for a recipe and you cannot keep adding genes." "you cannot make the genome step by step, like a recipe."
…I see no comparison	11%	"I see no comparison."
…it is too universal	9%	"the body cannot change by altering the recipe."
…the result is not working/living	8%	"food is not a working thing and a machine build from a blueprint is, just like your body."
…it is too adaptable	8%	"you often alter the recipe."
…the different levels are not visible	3%	"it does not contain different levels, like genes and proteins."

*Percentage of students that assess the recipe metaphor as not suiting.

Question 5

37 students could not mention a genome metaphor of their own. The remaining 112 students (76%) did answer question 5 by producing a genome metaphor. Analysis of question 5 shows a great variety in which genome metaphors students produce when describing the genome (see figure 5).

A majority of the students (21%) named a book/database metaphor, like a library or master brain. 18% produced a manual metaphor, like an IKEA manual or cake mix. 14% named a structure metaphor, like winding stairs. Building bricks and design metaphors were both produced by 13% of the students. Examples of building bricks metaphor are a mosaic or pieces of a puzzle. Examples of design metaphors are a sketch or building plan. 9% of the students named a code metaphor, like a cryptogram. 8% produced a community metaphor. They compared the genome to a class or school. The remaining 4% produced a switch panel metaphor, like settings or a sim card.

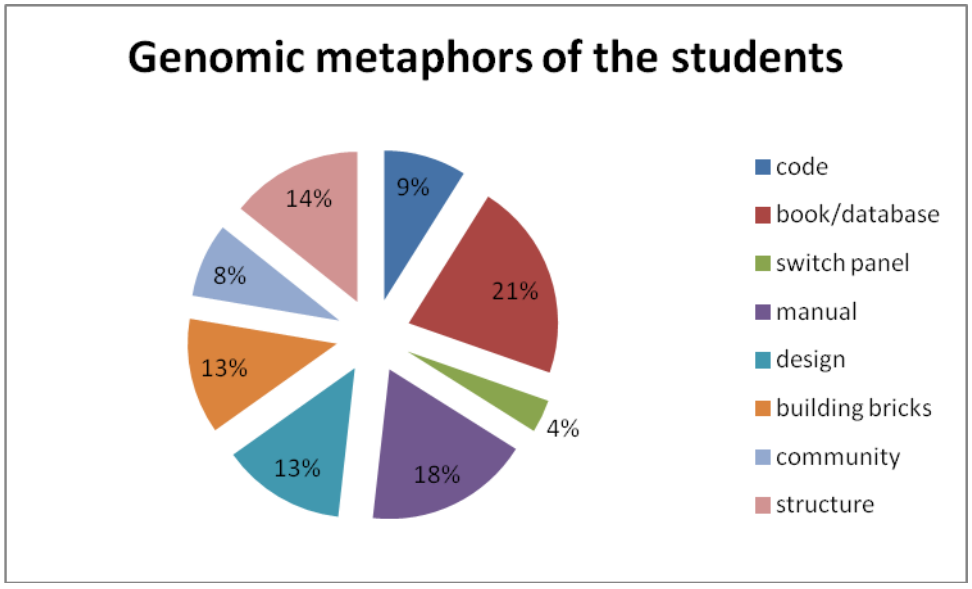

Figure 5: Pie chart showing percentage of students which use a certain genome metaphor.

Table 7: Categorization genome metaphors of the students				
Category*	***Definition***	***Examples***	***Theme***	***Quotes***
Code	The genome contains coded information that just has to be translated to form the organism.	Karyotype, puzzle, cryptogram, computer document (existing out of codes), code.	Language	"A cryptogram: answer everything correctly and you got the outcome."
Book/Database	The genome contains the information that has to be read to form the organism.	Book, bookcase, library, summary, dictionary, encyclopedia, map, hard disk, master brain, database, computer.	Language	"A library of your body, all information is saved in here." "A hard disk. Contains all that is known from the object (programmes, documents, etc). When something happens to the hard disk, the whole object is in danger. "
Switch panel	The genome consists out of settings that form the organism.	Sim card, settings, control panel, nuclear plant.	Machine	"… by switching on one button, something happens. By switching another button, something other happens. Which buttons you inherit depends from your parents."
Manual/supervisor	The genome contains fixed guidelines for the formation of the organism.	IKEA manual, instructions, description, cake mix, building instructions lego, supervisor.	Machine	"A manual of a lego building. This tells you whether to use blue or brown bricks etc." "A supervisor tells what has to happen, but sometimes […] something goes wrong causing a mistake in the outcome."
Design	The genome is the design of the organism.	Design, building plan, construction, template, sketch.	Machine	"A design of yourself. Both your inner and appearance is designed." "The genes are like the building plan of how you will become."
Building bricks	The genes in the genome are the building bricks that form the organism.	Mosaic, painting, building bricks, pieces of a puzzle, scoop candy, house, machine, soup, ingredients, box of bricks.	Machine	"Box of bricks: you can make everything from this and each building is unique, just like the genome." "A mosaic, small pieces with their own form and color, forming one whole together." "Like pieces of a puzzle that fit together and form an image."
Community	The characteristics of the organism are decided by the interaction of the different parts.	Class, school, core, community.	Machine	"Your genome is like a community, different parts (people) form together one individual (population).
Structure	The genome is a DNA structure.	Winding stairs, stairs, thread, ribbon, confetti.	-	"Stairs, two staircase railings with genes in between."

* Interrelated reliability about the categorization of the metaphors is ensured by an independent categorization of a sample from a second researcher which produced the same results for 100% of the sample.

Semantic scale

Question 6

Analysis of students' response to the semantic scales showed statistically significant differences in their perceptions of 12 of the 14 measured associations. On average, the blueprint metaphor was perceived as less variable, more fixed, more determined, more static and less active than the recipe metaphor (see table 8 and figure 6). The recipe metaphor was seen as more closely associated with smallness, as well as substantially more personal, simpler, friendlier and more malleable than the blueprint metaphor. The blueprint metaphor was seen as slightly more good than the recipe metaphor. There were no statistically significant differences in the students' sense of the blueprint and recipe metaphor as related to familiar or unfamiliar. Both metaphors were more closely associated with familiar than with unfamiliar. The same is true for the condition 'I use' versus 'others use'. Both metaphors were more closely associated with I use than with others use.

Table 8: Rating of connotations of blueprint and recipe metaphors.

	Blueprint		***Recipe***		
*Condition**	*Mean*	*SD*	*Mean*	*SD*	*p value***
small/large	3,22	1,20	2,84	1,11	0,00080
variable/uniform	2,93	1,16	2,52	1,15	0,00026
personal/industrial	2,51	1,39	2,11	1,11	0,00292
malleable/fixed	3,66	1,07	2,75	1,26	0,00000
good/bad	2,36	1,01	2,58	1,03	0,02599
complex/simple	1,68	0,85	2,49	1,31	0,00000
I use/others use	2,86	1,21	2,68	1,21	0,07889
free/determined	3,85	0,97	2,92	1,23	0,00000
friendly/threatening	2,81	0,81	2,59	0,83	0,00682
change/static	3,39	1,02	2,65	1,03	0,00000
I'm active/I'm passive	2,87	1,08	2,65	0,98	0,04365
familiar/unfamiliar	2,76	1,07	2,78	1,10	0,83564
unique/universal	1,96	1,11	2,37	1,21	0,00134
growth/halt	3,12	1,10	2,86	1,01	0,01100

*Variables are denoted as mean (SD). **Group differences were tested with two sample, paired Student T-test

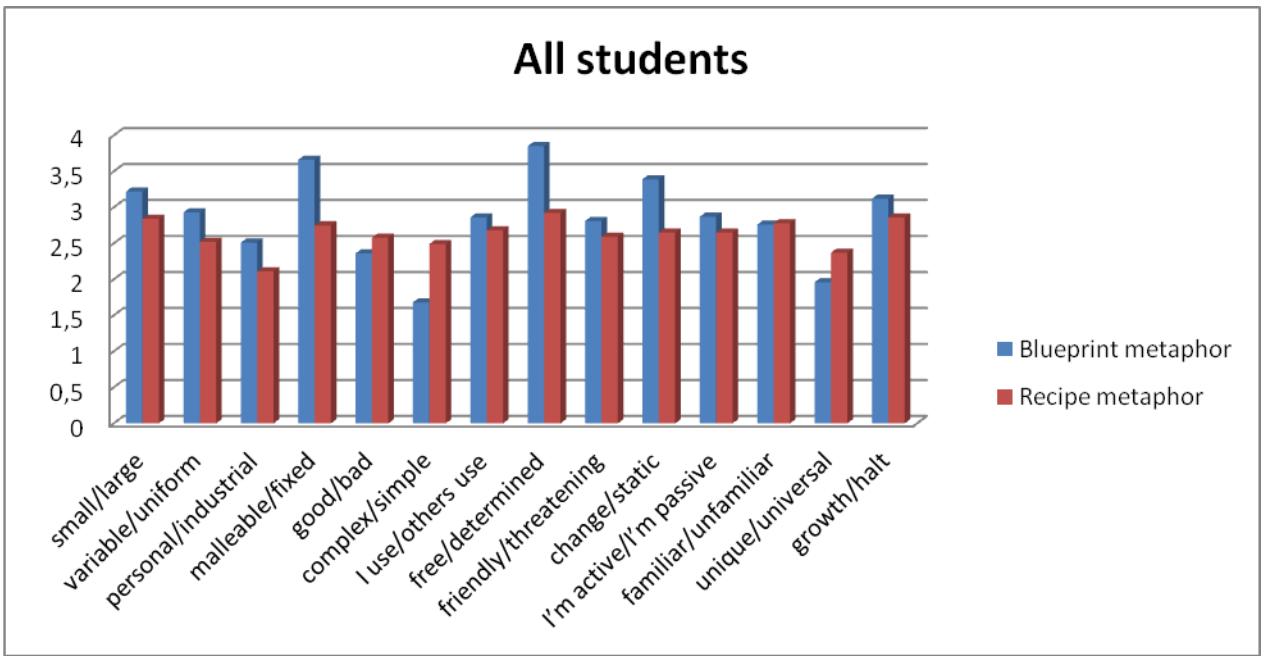

Figure 6: Graphic showing rating of connotations of blueprint and recipe metaphor. The first condition in each connotative pair is represented by the lowest rate (small is represented by 0 and large is represented by 5).

Question 7

Question 7 was answered by 76% of the students. 21% could not produce a genome metaphor. Analysis of the students' response to the semantic scales of their own metaphors shows the rating of connotations of student metaphors (see table 9 and figure 7).

On average, all metaphors were perceived as good and complex. Also, all metaphors were more closely associated with 'I use' versus 'others use'.
The code metaphor was perceived as most closely associated to passiveness and halt. The switch panel was rated smallest, most malleable, friendly, changeable, active, familiar and universal. The manual/supervisor metaphor was perceived as most closely associated to uniform, determined and unique. The design metaphor was rated most changeable an unfamiliar. It was also most closely associated to growth. The building bricks metaphor was perceived as most closely associated to variable and free. The community metaphor was rated largest. The structure metaphor was perceived most closely associated to personal, fixed and familiar.

Table 9: Ratings of connotations of students' metaphors																
	Code (n=10)		***Book/ Database (n=24)***		***Switch panel (n=4)***		***Manual/ Supervisor (n=20)***		***Design (n=15)***		***Building bricks (n=14)***		***Community (n=9)***		***Structure (n=16)***	
*Condition**	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
small/large	3,30	1,06	3,75	1,22	2,00	1,41	3,75	1,02	3,20	1,08	3,07	1,33	3,89	1,05	3,63	1,26
variable/uniform	3,40	1,17	2,58	1,18	3,00	1,83	3,45	1,05	2,73	1,28	2,36	1,39	2,67	1,00	2,75	1,34
personal/industrial	2,80	1,23	2,50	1,25	2,25	1,89	2,10	1,25	2,33	1,50	2,21	1,12	2,56	1,13	1,69	1,01
malleable/fixed	3,20	1,23	3,46	1,25	2,50	1,73	3,50	1,19	2,87	1,41	2,86	1,35	2,78	1,09	3,69	1,20
good/bad	2,40	0,70	2,38	0,82	2,00	0,82	2,30	1,03	2,33	0,72	2,21	0,97	2,33	0,87	1,94	0,93
complex/simple	2,40	1,17	2,33	1,27	2,50	1,29	2,80	1,24	1,93	1,16	2,29	1,20	2,22	0,67	2,19	1,38
I use/others use	2,40	0,97	2,50	1,06	2,75	1,71	2,00	1,03	2,60	0,83	2,21	0,89	2,78	0,83	2,56	1,03
free/determined	3,20	1,40	3,58	1,06	3,50	1,73	3,90	1,07	3,27	1,28	2,79	1,19	2,89	0,78	3,27	1,22
friendly/threatening	2,40	0,70	2,42	1,06	1,75	0,50	2,50	1,05	2,67	0,82	2,50	0,76	3,00	0,87	2,50	1,10
change/static	3,00	1,05	3,08	1,18	3,50	1,00	2,75	1,12	2,53	1,19	3,00	1,24	2,56	0,73	3,31	1,30
I'm active/I'm passive	3,30	1,06	3,00	0,88	2,00	0,82	2,70	1,26	2,47	0,92	2,71	1,07	2,44	0,53	2,44	1,03
familiar/unfamiliar	3,00	0,67	2,45	1,06	2,25	0,50	2,35	1,14	3,13	1,13	2,50	0,85	2,78	0,97	2,25	1,29
unique/universal	2,90	1,29	2,65	1,27	3,00	1,83	1,60	0,94	2,20	1,15	1,64	0,93	2,56	0,88	2,06	1,24
growth/halt	3,60	0,84	3,00	0,82	3,00	1,63	3,10	1,17	2,67	0,90	2,93	1,21	2,89	0,60	3,44	1,03

*Variables are denoted as mean (SD).

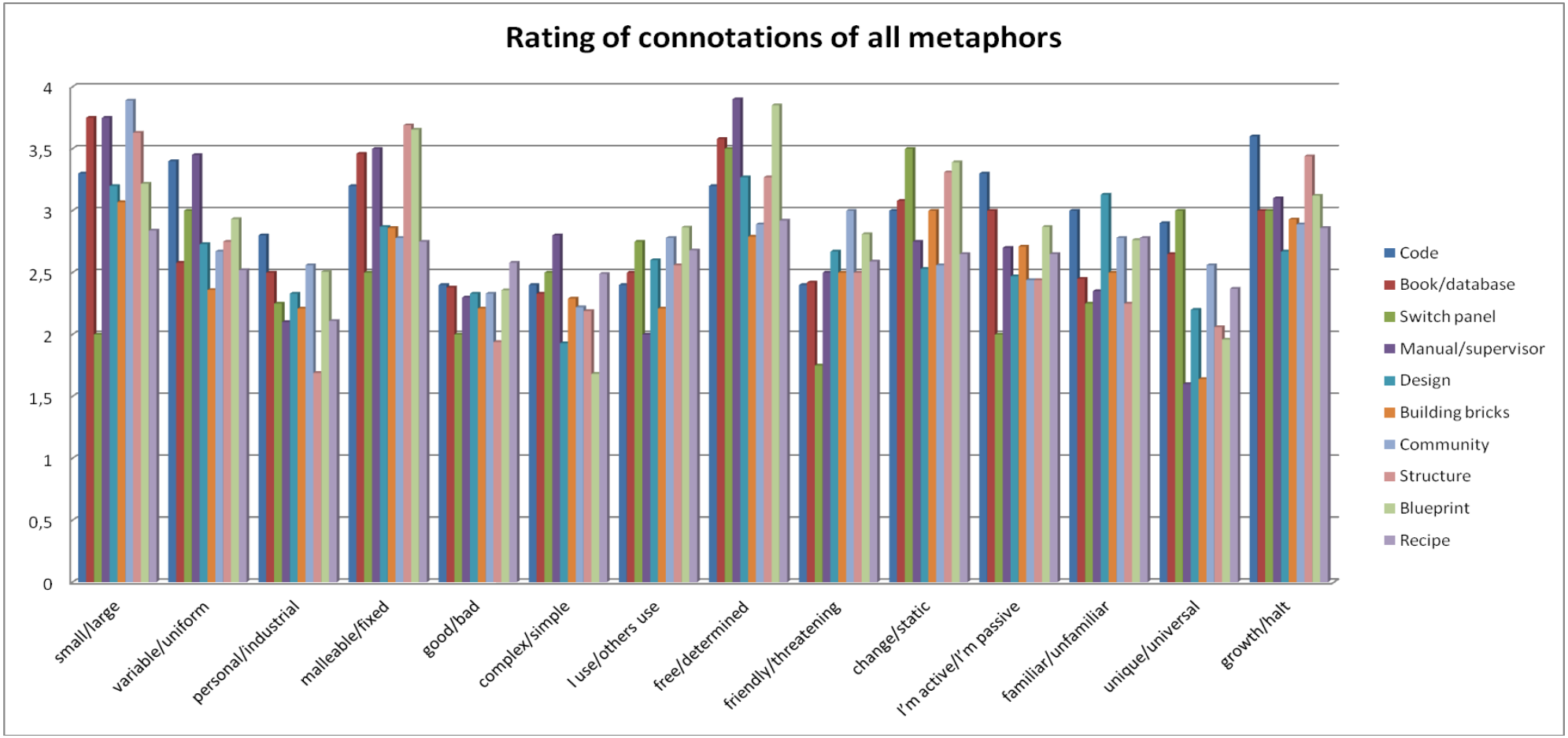

Figure 7: Graphic showing rate of connotations of student metaphors, blueprint and recipe metaphor. The first condition in each connotative pair is represented by the lowest rate.

Conclusion and discussion

Genomic view

The meaning secondary school students attribute to the genome in general and the origin of this genomic image was ascertained by studying the answers to question 1, 2 and 3 of the survey.
Most students that participated in this study think about their genome during biology class (39%: question 1). 18% of the students state that they never think about their own genome. 5% mention they think about their genome when studying the structure or by different media. These groups together form a majority of 62% that do not see a personal relation to the genome. The remaining 38% of the students relate the genome more to their personal live, by stating they think about the genome when they think about heredity.
74% of the students think about genomic structure after thinking about the genome (question 2). Heredity (genomic function) was only mentioned by 19% of the students.
This together implies that the genome does not have much daily life meaning or value for the students. A great majority of the students (77%: question 3) mention that they acquired their genomic image from school.

Blueprint and recipe metaphor

The meaning and values secondary school students attribute to the recipe and blueprint metaphor was studied via question 4 and 6. The result of these questions is compared to the opinion of the experts in literature.

Analysis of question 4 shows that a majority of the students (57%) has a preference for the blueprint metaphor. They describe this metaphor as more complete, detailed and fixed, by stating that "your genome tells in great detail how to build a person". This is consistent with the expectations of proponents of the recipe metaphor, who state that the blueprint metaphor emphasizes a deterministic genomic image by comparing the genome with a design that only has to be executed (Condit *et al*, 2002; Condit, 2004). Analysis of all students' response to the semantic scales (question 6) showed indeed that the blueprint metaphor was perceived as more deterministic by the students. They rate the blueprint metaphor in general less variable, more fixed, more determined, more static and less active than they perceived the recipe metaphor. These findings support the expectations of the proponents of the recipe metaphor, namely that the blueprint metaphor is more deterministic. These students assess the blueprint metaphor as too fixed by stating that "everything is determined in advance and has to be executed this way exactly in order to function in the right manner". This minority also criticizes the blueprint metaphor, because they perceive it as too uniform and unnatural.

Only 11% of the students have a preference for the recipe metaphor. These students evaluate the recipe metaphor as more suiting describe this metaphor as more complete, variable and original. The students state that the recipe metaphor is more complete, because the role of genes and proteins is more visible and the action plan is clearer. They also evaluate this metaphor as more variable. This is consistent with the expectations of Rothman (1998), who states that the recipe metaphor has individual diversity and variability built in it. Analysis of students' response to the semantic scales (question 6) showed indeed that the recipe metaphor was seen as more variable, malleable and free than the blueprint metaphor. This metaphor was also closer associated to small, personal, simple, friendly and change. On average, the students rate the recipe metaphor as less deterministic than the blueprint metaphor. This is consistent with the expectations of Hubbard and Wald, who state that the recipe metaphor was less deterministic, taking away the "aura of inevitability which limit us" by encouraging "adaptability and flexibility". The

statement of Rothman that the result is dependent of the different ingredients was also supported by the students, who state that “the ingredients (genes) of both parents are mixed”.
The students criticize the recipe metaphor for its randomness and simplicity by stating that “your genome is not just a soup with randomly chosen ingredients, it exists thanks to inheritance” and “food is not a working thing and a machine build from a blueprint is, just like your body”. Also, 12% states that the recipe metaphor is not suiting, because the genome does not follow an action plan like this metaphor implies. This is inconsistent with the view of Rothman, who states that the recipe metaphor is suiting because the result is dependent of the different proceedings.
The view of Hubbard and Wald (1993), who state that genes and environment are the ingredients, which can be used actively by the cell (the cook) to form the phenotype, was not supported by the students. Gene-environment interactions are not mentioned by the students.
Both metaphors were more closely associated with familiar than with unfamiliar.

Students’ genomic metaphors

Question 2, 5 and 7 are designed to find out which other genome metaphors students use and to describe the meaning and values of these metaphors.
In question 5 the students had to produce a genome metaphor by themselves. Question 7 was used to study the meaning and values of these genome metaphors. 76% of the students answered this question. The frames of Carver *et al* (2008) were also used in order to categorize the students’ genome metaphors. In order to determine whether a certain metaphor could be called deterministic, the connotative pairs ‘variable/uniform’, ‘malleable/fixed’, ‘free/determined’ and ‘change/static’ were closely studied for each metaphor.

Most students (21%) produce a book/database metaphor. In the book/database metaphor, the genome was described as the storage of information to form an organism. This differs from the frame of Carver *et al*, who frame the book metaphor materialistic. In this study, the students describe the book/database metaphor as rather deterministic. It was classified as deterministic, because it rated more fixed than malleable (3,46) and more determined than free (3,58). However, this metaphor was also rated more variable than uniform (2,58), which means that the students which preferred this metaphor see that the genome varies among people.
18% of the students produce a manual/supervisor metaphor. This metaphor is describing the genome as guidelines to form the organism. The students perceived the manual/supervisor metaphor as the most uniform and unique metaphor. The students seem to understand that the genome varies among people, but also think it is uniform to a certain limit. They associate this metaphor most closely to determined and to their own use. Also, this metaphor was rated more fixed than malleable (3,50). Altogether, these results show the students describe the manual/supervisor metaphor as rather deterministic. This is fitting with the frame of the manual metaphor according to Carver *et al.*
Another 13% produced a design metaphor. In this metaphor, the genome was described as a design or building plan in the design metaphor. This metaphor was closes associated to complexity, change and growth. It was also rated most unfamiliar. Adjacent, this metaphor was rated more variable than uniform (2,73), slightly more malleable than fixed (2,87) and more changeable than static (2,53). However, this metaphor was also rated more determined than free (3,27). This together with the student quotes proves the design metaphor is described rather deterministic by the students. Carver *et al* did not produce a frame for this specific metaphor, but the description fits with the deterministic frame.
9% describes the genome as a code metaphor. They describe the genome as coded information that just has to be translated to form an organism. The code metaphor was perceived as the least personal metaphor. This metaphor was also most associated to passive. Beside this, the code metaphor was rated more uniform than variable (3,40), more fixed than malleable (3,20) and more determined than free (3,20). Altogether, this shows a rather deterministic genomic view for the code metaphor. This differs from the frame of Carver *et al*, who frame the book metaphor materialistic. However, in this study the students describe the code metaphor as rather deterministic.

The switch panel metaphor is produced by 4% of the students. In the switch panel metaphor, the genome consists out of different settings that form and could change the organism. The switch panel metaphor was perceived smallest, most friendly and passive. It was also most closely associated to static and malleable, which contradicts each other. This may be caused by the small number of students which rated this metaphor. This metaphor was perceived as most familiar (together with the structure metaphor). The switch panel metaphor was rated more malleable than fixed (2,50), but also more determined than free (3,50) and more static than changeable (3,50). This proves this metaphor is described rather deterministic by the students. According to Carver *et al*, the switch panel metaphor could be framed evolutionary. The students mention words like "respond" and "turn on/off". However, an interaction with the environment was not mentioned. That is why the switch panel metaphor was also framed deterministic in the recent study.

In all the above metaphors, the genome is described as a rather deterministic entity. The information is given, in the form of a code, book, manual or design and the organism is built exactly from this information. When there is a mistake present in the information, the organism will not function properly. Gene-environment interactions or epigenetics are not mentioned by the students.
The building bricks metaphor and the community metaphor were not described as deterministic. These metaphors were produced by 21% of the students.
The building bricks metaphor was produced by 13% of the students. In the building bricks metaphor the genome was compared to some sort of creation, build from pieces. The building bricks metaphor was perceived as the freest metaphor. It was also most closely associated to variable. Next to this, this metaphor was rated more malleable than fixed (2,86). This metaphor is rated less deterministic and freer by the students. According to Carver *et al*, the building bricks metaphor could be framed materialistic.
In the community metaphor (8%), the characteristics of the organism are decided by the interaction of the different parts. The community metaphor was perceived as threatening and large. The community metaphor was rated more variable than uniform (2,36), slightly more malleable than fixed (2,78), slightly more free than determined (2,89) and more changeable than static (2,56). This proves this metaphor as not deterministic per se. A suiting frame from Carver *et al* was not found.
The remaining students (14%) came up with a materialistic (Carver *et al,* 2008) structure metaphor. The students describe the genome as a physical entity defined by a particular fragment or sequence of the DNA molecule. Most structure metaphors describe the structure of the genome in an artistic manner. The structure metaphor was perceived as the most personal, fixed, good and familiar (together with the switch panel metaphor).This metaphor was rated more variable than uniform (2,75). However, it was also rated more fixed than malleable (3,69), more determined than free (3,27) and more static than changeable (3,31). This proves this metaphor also as rather deterministic.
Concluding, 79% of the students produce a deterministic genome metaphor. Only the community and the building bricks metaphor were perceived as free. However, this does not necessarily mean that the students have a deterministic view in different situations.

Relations to school knowledge

According to the Dutch syllabus for biology, "the examinee has to be able to explain heredity in the organism by describing processes at lower levels and is able to discuss human interference in these processes" (syllabus biologie VWO central examen 2012, domain C1 heredity). This is clearly linked to genomic function. However, analyzing question 2 displays almost three quarters of the students think about genomic structure after thinking about the genome. They name terms like DNA strands, chromosomes, DNA, double helix and genes. A minority of 19% thinks about genomic function directly after thinking about the genome. They name phenotypical traits, like eye and hair color, heredity, diseases and karyotypes. This distribution shows an emphasis on genomic structure rather than on genomic function among high school students. Since most students that participated in this study think about their genome during biology class (39%; question 1) and a great majority of students (77%;

question 3) mention that they acquired their genomic image from school, this could mean that genomic structure receives more focus in upper secondary biology education than genomic function.
The students seem to have a preference for rather deterministic metaphors, which could mean that the have deterministic images of the genome. A majority of the students (86%) named a deterministic genome metaphor, like a code, book/database, switch panel, manual, design, building bricks or community. 57% of the students has a preference for the blueprint metaphor. They describe this metaphor deterministically by stating that "your genome tells in great detail how to build a person". This is possibly caused by the emphasis on both Mendelian genetics and human interference in Dutch genetics education which do not leave much room for environmental influences. An emphasis on these subjects could also cause a deterministic genomic view among students.

Implications

This study shows that most students have rather deterministic images of the genome. Education could counterbalance determinism by using an appropriate combination of metaphors, including metaphors that leave more space for epigenetics and gene-environment interactions.
For example, Avise (2001) compares the genome to a small ecosystem, in which every gene has its own functional niche. The DNA interacts with other factors, which can be compared to mutualism in which both parties benefit from this interaction.
The blueprint and recipe metaphor can be just as helpful for education as new metaphors. However, it is very important to use metaphors in the right manner. Therefore, a teacher always has to mention that the metaphor is just a way to explain and clarify genomic function, and that there is no one to one comparison between the metaphor and the genome. To ensure that a metaphor does not convey unintended meanings, it is desirable to emphasize gene-environment interaction and epigenetics when using metaphors. It is important to mention that two organisms with the same genes will manifest in different forms, behaviours and life courses in different environments, because of the interaction of different environmental factors. It is also important to emphasize that a certain characteristic or disease is almost never caused by a single-gene.

Future research

Further study could further explore how biology education influences the genomic view of students. This could be done by studying the genomic view of eleventh grade students who do not follow a biology course. Further research could also study differences in perceptions of genome metaphors between biology teachers and students. The semantic scales used in this study can be used to study how teachers perceive genome metaphors. Since Condit *et al* (2002) suggest that females have been more conditioned to traditional mores and therefore be more familiar with recipes than with blueprints; it would be also interesting to study differences in female and male responses to both metaphors. Results of both studies can be compared by the results of this study, in order to discover differences and similarities between different target groups. Finally, interviews with students could reveal whether their use of a deterministic metaphor indicates also a deterministic image of the genome in different situations.

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Attachment I – Semantic scale and questionnaire

Wat vind jij van jouw genoom?

Je ***genoom*** is het complete erfelijke materiaal in je cellen. Het is de verzameling van al je ***genen***. Wanneer wetenschappers het over "het genoom" hebben, gebruiken ze verschillende ***metaforen*** (vergelijkingen). Sommige wetenschapers vergelijken het genoom met een ***blauwdruk***. Een blauwdruk is een gedetailleerd ontwerp van een gebouw of voertuig. Andere wetenschappers vergelijken het genoom liever met een ***recept*** uit een kookboek. Waar denk jij aan bij deze metaforen voor het genoom?

1) Wanneer denk jij na over je eigen genoom/je genen/je DNA en waar denk je dan aan?

……

……

……

2) Welk beeld schiet jou meteen te binnen als je over het genoom nadenkt?

……

3) Waar komt jouw beeld van het genoom vandaan?

0 School: biologieles, leraar, boeken, plaatjes.
0 Thuis: familie, vrienden, kennissen.
0 Media: documentaire, krant, nieuws, tv, tijdschriften.
0 Anders, namelijk ……

4) Welke van de twee metaforen (blauwdruk en recept) vind jij het best passen bij het genoom? Beschrijf voor beide metaforen waarom je deze wel of niet passend vindt.

De blauwdruk vind ik wel/niet passend, omdat……

……

Het recept vind ik wel/niet passend, omdat……

……

5) Als je niet de blauwdruk en/of recept-metafoor mag gebruiken, hoe zou je het genoom dan omschrijven? Beschrijf je eigen metafoor voor je genoom en waarom je dit een geode vergelijking vindt.

……

……

6) Zet een kruisje op de plaats waar jij denkt dat het genoom staat ten opzichte van de begrippen. Bijv.: als jij denkt dat het woord “snoep” dichterbij “zoet” staat dan bij “zuur”, dan vul je dit als volgt in:

			Snoep			
Zuur	_	_	_	x	_	Zoet

Het genoom is als een blauwdruk

Klein	_	_	_	_	_	Groot
Variabel	_	_	_	_	_	Uniform
Persoonlijk	_	_	_	_	_	Industrieel
Veranderbaar	_	_	_	_	_	Vast
Goed	_	_	_	_	_	Slecht
Complex	_	_	_	_	_	Simpel
Ikgebruik het	_	_	_	_	_	Anderengebruiken het
Vrij	_	_	_	_	_	Bepaald
Vriendelijk	_	_	_	_	_	Dreigend
Flexibel	_	_	_	_	_	Statisch
Actief	_	_	_	_	_	Passief
Bekend	_	_	_	_	_	Onbekend
Uniek	_	_	_	_	_	Universeel
Groei	_	_	_	_	_	Stilstand

Het genoom is als een recept

Klein	_	_	_	_	_	Groot
Variabel	_	_	_	_	_	Uniform
Persoonlijk	_	_	_	_	_	Industrieel
Veranderbaar	_	_	_	_	_	Vast
Goed	_	_	_	_	_	Slecht
Complex	_	_	_	_	_	Simpel
Ikgebruik het	_	_	_	_	_	Anderengebruiken het
Vrij	_	_	_	_	_	Bepaald
Vriendelijk	_	_	_	_	_	Dreigend
Flexibel	_	_	_	_	_	Statisch
Actief	_	_	_	_	_	Passief
Bekend	_	_	_	_	_	Onbekend
Uniek	_	_	_	_	_	Universeel
Groei	_	_	_	_	_	Stilstand

7) Vul deze figuur op dezelfde manier in voor je eigen bedachte metafoor uit vraag 5.

Het genoom is als een ……

Klein	_	_	_	_	_	Groot
Variabel	_	_	_	_	_	Uniform
Persoonlijk	_	_	_	_	_	Industrieel
Veranderbaar	_	_	_	_	_	Vast
Goed	_	_	_	_	_	Slecht
Complex	_	_	_	_	_	Simpel
Ikgebruik het	_	_	_	_	_	Anderengebruiken het
Vrij	_	_	_	_	_	Bepaald
Vriendelijk	_	_	_	_	_	Dreigend
Flexibel	_	_	_	_	_	Statisch
Actief	_	_	_	_	_	Passief
Bekend	_	_	_	_	_	Onbekend
Uniek	_	_	_	_	_	Universeel
Groei	_	_	_	_	_	Stilstand