Attitudes of Secondary School Students towards Modern Biotechnology

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Attitudes of Secondary School Students towards Modern Biotechnology

Attitudes van middelbare scholieren ten aanzien van moderne biotechnologie

PROEFSCHRIFT

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Voor mijn lieve moeder en mijn lief

Contents

Voorwoord

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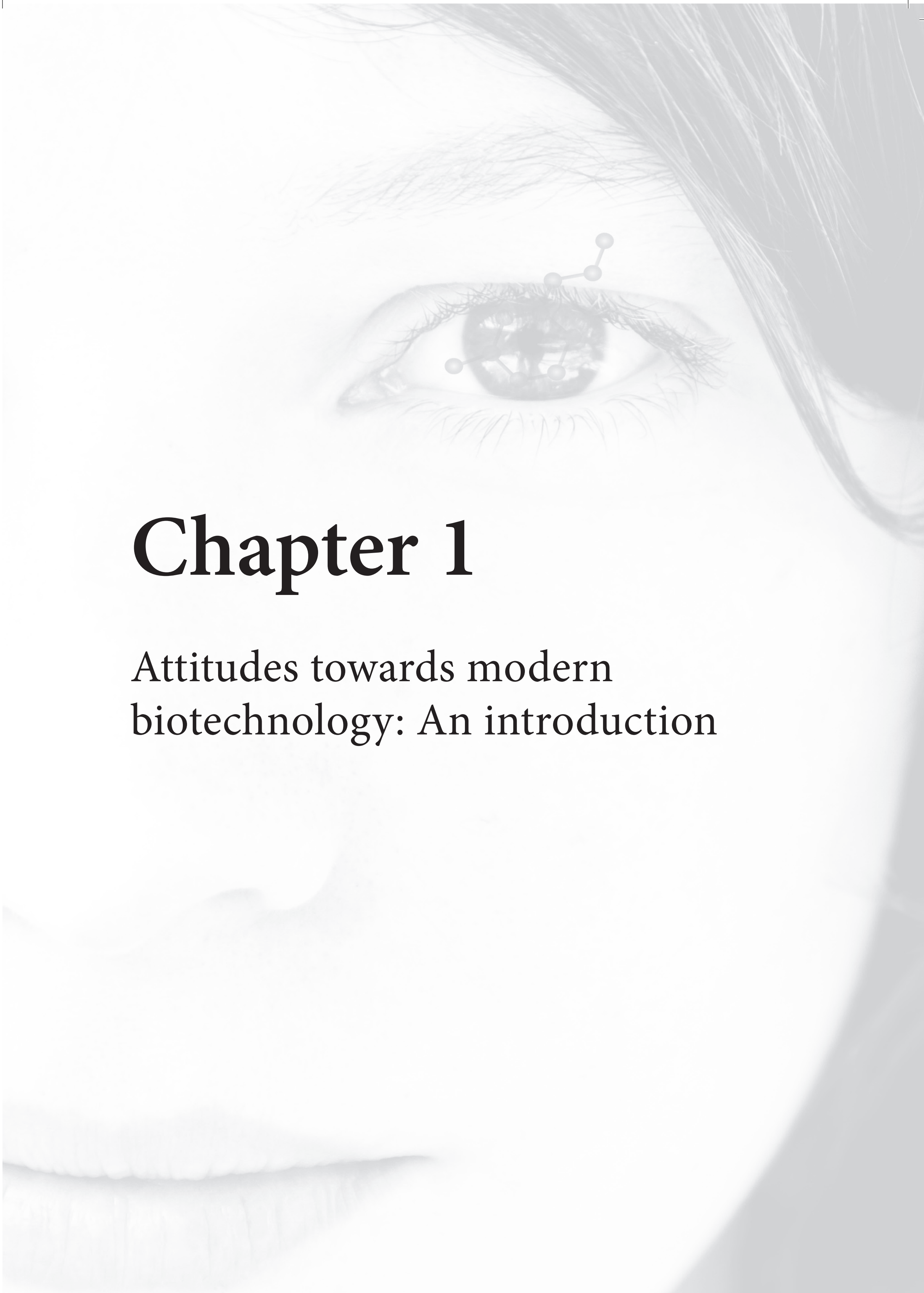

Chapter 1

Attitudes towards modern biotechnology: An introduction

~ "*The learner's attitude is thus an essential factor to determine the direction of his learning, whether he shall learn to do or not learn to do.*" ~
(William Kilpatrick, Prof of Education 1917)

I interviewed a group of four sixteen-year old secondary school students about their attitudes towards modern biotechnology. When I asked them what they knew about this subject, one girl responded: "*Well, I know it's about genes, they are located in your DNA, and within your genes is all the information for your body …or something like that*." Her fellow student immediately reacted: "*It's about genetic manipulation; they can change something without you knowing about it*." One of the two boys in the group could not care less and just said: "*It's boring! It is something for smart people, not for me*." When I asked them about their feelings towards it, the first girl said: "*I find it very interesting and fascinating, that they can do stuff like that*." The other girl was not that convinced, and replied: "*I think it's like playing God, manipulating everything can not be good*." While the other boy in the group had not made up his mind: "*I really don't know what to think about it now, no one in my family is sick or anything, so for now it does not concern me*."

Four students with four different ways of looking at and responding to modern biotechnology; one of the girls in the group was very aware and interested, while the other girl was reluctant. One boy did not really care, while the other boy was not sure what to think of it. They all differed in their knowledge, feelings and beliefs, but they all had some kind of attitude towards modern biotechnology.

In this dissertation, two issues with regard to the interaction of modern biotechnology and secondary school students will be investigated. The first issue concerns the question what young people currently know about modern biotechnology, and what their underlying views and opinions are. In other words, what are the attitudes towards modern biotechnology of secondary school students? This introduction will present a description of modern biotechnology (genomics), followed by the concept of attitudes, and attitudes towards modern biotechnology. Students' attitudes towards modern biotechnology constitute the building blocks of this thesis.

The second issue examines the way science education may help students not only to develop their levels of knowledge, but also to invite students to reflect upon modern biotechnology and develop their attitudes to more profound levels. The need for scientific literacy and the role of science education herein is highlighted.

In the last two sections of this introduction, the problem statement and research questions are formulated and a brief overview of the chapters of this thesis is presented.

1. Modern biotechnology

Genomics and its associated technologies (or modern biotechnology) are set to become one of the most important scientific and technological revolutions of the 21st century (Kirkpatrick, Orvis, & Pittendrigh, 2002). Genomics is the characterization and sequencing of an organism's genome, and analysis of the relationship between gene activity and cell function. It is a fast growing interdisciplinary field of research aimed at collecting, understanding, and exploiting the biological information encoded in DNA. Recent advances in genomics are bringing about a revolution in the understanding of the molecular mechanisms of, among others, diseases. It includes the complex interaction of genetics and environmental factors, thereby stimulating the discovery of breakthrough healthcare. Genomics also includes genomic characterization of (farming-) animals[1] and fish, (crop) plants, trees, bacteria, viruses and other micro-organisms. It can be divided into 'structural genomics'; the development of genome maps and sequences; and 'functional genomics' or the discovery of biological function of particular genes and how these work in the context of the whole genome of the organism.

Modern biotechnology is the term used to incorporate the vast (and growing) range of techniques for modifying life forms for research (medical, environmental, agricultural) and commercial uses. The utilization of modern biotechnology will ultimately alter our health care, industry and agriculture (e.g. Gaskell, Allum, Stares, & et.al., 2003; Heijs, Midden, & Drabbe, 1993; Kirkpatrick et al., 2002; Macer, 1992; Pardo, Midden, & Miller, 2002; Waarlo et al., 2002) and with this perspective, it will greatly influence various aspects of our current society as we know it [2].

As such, it is important that the public understands the main concepts behind modern biotechnology. Especially youngsters of today will need such knowledge in their future careers and in their daily lives as members of this fast changing society, in order to make personal and social choices about issues related to science and technology. For this reason, it has been recognised that a major goal of school science education must be the promotion of scientific literacy. With this, we mean the development of understanding and habit of mind needed to become responsible human beings able to think for themselves and to function effectively in an increasing complex and technology dependent society (Bingle & Gaskell, 1994; Dimopoulos & Koulaidis, 2003; Jenkins, 1992, 1997; Miller, 1998; Welch, 1985).

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[1] Also of humans, known as human genome-project (HUGO), a project about mapping the human genome.

[2] Therefore, we will use the term (modern) biotechnology throughout this thesis, instead of genomics.

2. What is 'an attitude'?

Most people have more or less profound attitudes towards an endless number of objects. We have no difficulty in expressing our attitudes towards Prime Minister Balkenende, genetically modified tomatoes, or 'young people nowadays' (attitude objects). If we have a positive attitude towards minister Balkenende, then we will probably say nice things about him, and support his policies, we might even vote for him. A negative attitude towards genetic modified tomatoes might imply that we will make critical comments about it; we will probably not buy nor eat these tomatoes. However, the extent to what we intend to do and what we eventually do depends on the attitude itself; how strongly we feel about the object, and to what extent we can influence our behaviour.

Attitude is a central concept in a large body of social science research; in the field of social psychology, it is perhaps the most essential concept. This enormous research area has resulted in complex and diverse conceptualisations of attitudes. However, there seems to be a general agreement that an attitude represents a summary evaluation of a psychological object captured in such attribute dimensions as good-bad, harmful-beneficial, pleasant-unpleasant and enthusiastic-uninterested (Ajzen, 2001; Ajzen & Fishbein, 2000; Eagly & Chaiken, 1993).

In noting the variety of definitions that have been offered for attitudes, authors have often been reluctant to suggest that one definition is better than the others are. Accordingly, many reviewers have supported definitions that;

- permit a broad array of research operations for attitude measurements, and
- put no apparent boundaries on the sort of entity that can be regarded as the object of an attitude (e.g., Allport, 1935; Defleur & Westie, 1963; Greenwald, 1968).

Central to the concept of attitudes is its evaluative quality. Attitudes are more than opinions or reflections. A person's attitude influences the way things are perceived, experienced, and thought about. Strong attitudes can be described as resulting in selective cognitive processing and will be resistant to change, persistent over time, and highly predictive of behaviour (Eagly & Chaiken, 1993; Eagly & Chaiken, 1995).

2.1. Attitude towards modern biotechnology

Attitudes have generally been inferred not from the observation of actual behaviour but from individuals' responses to survey questionnaires (Pardo et al., 2002). Most research on attitudes towards biotechnology measures attitude as a one-dimensional concept by the question 'how do you feel about certain biotechnology issues'. Not only do we consider attitude to be a more complex construct than 'a feeling towards', but also science or biotechnology is a too much of a complex subject to be seen as one object (Pardo & Calvo, 2002). Because of the variety of definitions of attitudes, the concept used in our analyses will be described in detail.

In this thesis, we describe the concept of attitude based on the theoretical tripartite model of attitudes (Breckler, 1984; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960). This model encompasses three basic attitude components: an affective, a cognitive, and a behavioural component.

"We here indicate that attitudes are predispositions to respond to some class of stimuli with certain classes of responses and designate the three major types of responses as cognitive, affective, and behavioural." (Rosenberg & Hovland, 1960, p.3)

The concept of attitude towards modern biotechnology can be described as follows (Figure.1):

- The cognitive component is the evaluation of modern biotechnology that follows from beliefs, thoughts, and (previous) knowledge of the object.
- The affective component of attitudes reflects how students feel about genomics, for instance anxieties and fears about this contemporary technology.
- The behavioural component is in this particular study difficult to operationalise. Secondary school students usually have not encountered any contexts in which they had to act or make a decision regarding biotech issues. Therefore, we decided to describe behavioural intentions as a proxy for actual behaviour. Behavioural intentions can be described by outlining situations in which one does or does not act (protest against genetic modification of crop), buy (jeans made of genetically modified cotton), or use (genetic screening).

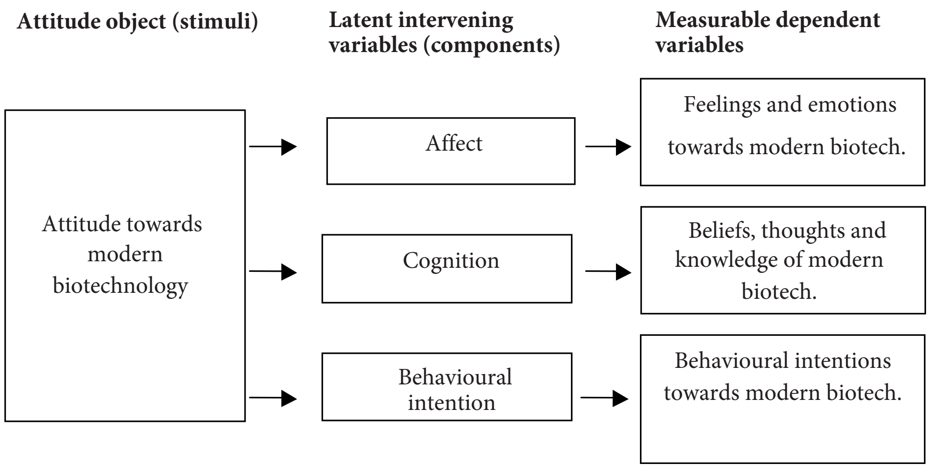


Figure 1. Conceptual framework of attitudes

These components, however, do not simply add up to an overall attitude. The overall attitude is dependent on the accessibility of beliefs and the tendency of individuals to base attitudes on the cognitive or affective component. Moreover, attitudes toward some biotechnological applications or objects might rely more on affect than on cognition (for example cloning), whereas the opposite is true for other objects (Ajzen & Fishbein, 2000; Heijs et al., 1993). It has been argued that attitudes towards complex and diverse constructs, such as modern biotechnology, are based more on 'gut' reactions than on logical thinking (Ajzen, 2001; Ajzen & Fishbein, 2000; Heijs et al., 1993; Pardo et al., 2002; Zajonc, 1980). Moreover, the subject of modern biotechnology holds several dimensions that are important to the public and are too complex to be measured as a uni-dimensional attitude-object. One must reckon with at least the most common, and for the public most significant fields of research: medical, agricultural and industrial, classified into the domains of humans, animals, plants, micro-organisms and industrial uses.

3. Scientific literacy and science education

In this thesis, two areas of research are brought together. Central concept in the first area is attitude. The concept of attitude appeared to be the most suitable concept in light of the first issue in this thesis: a description of the way students feel about modern biotechnology in relation to their knowledge levels and behavioural intentions. In this second area of research, the concept of scientific literacy is paramount: the most basic goal of school science education is to develop scientific literacy among students.

Before introducing the field of science education and scientific literacy, we will first clarify the relationship between the concepts of attitude in the first part of the thesis and scientific literacy in the second part of the thesis.

An analysis of the concepts of attitude and scientific literacy shows a close resemblance. As described above, in the tripartite attitude theory, attitude is conceptualised in terms of a cognitive, affective, and behavioural component. Similarly, being a scientifically literate person generally implies possessing a set of cognitive, affective and behavioural abilities, needed to function effectively in an increasing complex and technology dependent society and to understand the essence of competing arguments on a given controversy (Bingle & Gaskell, 1994; Dimopoulos & Koulaidis, 2003; Jenkins, 1992, 1997; Miller, 1998; Welch, 1985). In this particular division in three components (cognitive, affective, and behavioural), the two concepts meet. However, the concepts are not exchangeable. Attitude is a 'descriptive concept'; some attitudes are less profound then others, some may be based on sound scientific knowledge, or on misconceptions. How the three basic components relate to each other can differ, resulting in different attitudes. Scientific literacy, on the other hand, is a normative concept; one needs a certain level of scientific literacy in order to function effectively as a citizen and consumer in our technologically driven society.

In the context of science education, discussions about required and sufficient levels of scientific literacy exemplify its normative character.

Given its central role in science education, we choose to use the concept of scientific literacy instead of the concept of attitude in the second part of the thesis. In order to examine effects of science education on scientific literacy, it is important to use a measure that will be sufficiently sensitive to capture changes in the structure of its composition (Millar, 2006). Therefore, the attitude instrument as developed in the first part is used as a framework to indicate development in scientific literacy in the second part. Regardless of the descriptive versus normative character of the two concepts, the conceptual similarity in terms of their underlying components, this link seems justified.

3.1. Scientific literacy

As a scientific discipline, modern biotechnology goes hand in hand with cultural, social, and public policy controversies. People should be able to make informed and balanced decisions about scientific issues that concern their careers, their daily lives, and society as a whole (National Academy of Sciences, 1996). To be able to do this requires a certain level of scientific literacy. However, when it comes to actually defining scientific literacy, there is a considerable variation regarding its meaning (DeBoer, 2000; Hodson, 2002; Laugksch, 2000). Conceptualisations of scientific literacy range from understanding lay articles in newspapers and popular magazines of (modern) scientific issues (Millar & Osborne, 1998; Miller, 2007), an appreciation of the nature, aims and general limitations of science (Jenkins, 1992), to the abilities of a semi-professional scientist (Hazen & Trefil, 1991; Thomas & Durant, 1987). In this thesis (and as far as modern biotechnology is concerned) we conceptualised scientific literacy as having an accurate knowledge base on basic biological and genetic concepts, displaying an affective reaction of concern or comfort towards biotech issues, and having clear ideas on how to behave or make decisions when confronted with modern biotechnology (in accordance with Millar, 2006; Millar & Osborne, 1998; National Academy of Sciences, 1996).

There are a number of reasons why scientific literacy is considered important. The society we live in depends to an ever-increasing extent on technology and the scientific knowledge that makes it possible. If we merely look at the utilization of modern biotechnology and the effects it will have on our health care, industry, and agriculture, every decision we make will have the capacity to ultimately affect the wellbeing of our community, the world, and ourselves.

The number of times we come into contact with scientific information and are required to make decisions based on that information is also increasing: think about food labels, medication labels, technical information for new products and newspapers with headline stories that suggest breakthrough 'cures' have been found. How do you know what to believe? How do you know what to do or how to act? Would you be able to determine if the information is truthful and/or realistic? All this deals with issues that directly affect your life; as a consumer, as a business professional, as a citizen. You will have to form opinions about these and other science-based issues if you are to fully participate in our modern society.

Promoting scientific literacy is widely recognised as a major goal of school science education (Millar, 2006). Likewise, there are varying interpretations of how and what kind of abilities should be incorporated into school science curricula in order to help students become scientific literate. The question is what is important for students to know, value, and be able to do in situations involving science and technology?

3.2. Science education

The interpretation of scientific literacy mentioned above shows that it is important that people understand how science, technology and society influence one another and are able to use this in everyday decision making (Driver, Newton, & Osborne, 2000; Kolstø, 2001). Therefore, the purpose of science education should be helping students to be able to participate in discussions about science, to be sceptical and questioning of claims made by others about scientific matters, and to make informed decisions about the environment, their own health and well-being (in accordance with Driver et al., 2000; Goodrum, Hackling, & Rennie, 2001; Kolstø, 2001; National Science Council, 1996). According to Osborne (2000), this broad focus will help students to tackle everyday decisions with a science or technology dimension, such as whether to buy a tube of genetically modified tomato paste.

The question is how this ability may be fostered within science education; how can students be encouraged to develop scientific literacy within a school setting?

Developing scientific literacy is affected by many variables. Research studies, reviews, and summaries of research in science education since the 1970s report that hands-on, activity-based instructions enhance scientific literacy (Fraser, 1980; Freedman, 1997; Johnson, Ryan, & Schroeder, 1974). Instructions that make science exciting and encourages students to participate (e.g., laboratory setting), have a positive impact on their attitude towards science (Bennett, 2001). Several successful design principles can be deducted from research on science education. These principles are generally inspired by a social constructivist perspective on learning. In the following sections, the main design principles discerned in this thesis will be discussed against the background of a social constructivist perspective on learning.

3.2.1. Social constructivist perspective on learning

Traditional science teaching concentrates on the direct transmission of knowledge or facts from teachers to students and thereby involves mostly non-interactive teaching activities. The norm of traditional teaching is that teachers explain science concepts to the whole class, and students are passive receivers; listening, taking notes and memorizing the knowledge or facts.

Constructivism can be seen as a reaction to this form of teaching and learning, which has been severely criticised. Constructivists consider learning an active construction of knowledge, based on what the learner already knows (Driver et al., 1994; Duit, 1994; Tobin, 1993; Appleton, 1997). By reflecting on experiences, we construct our own understanding of the world we live in; we generate our own 'rules' and 'mental models', which we use to make sense of our experiences. Learning, therefore, is the process of adjusting mental models to accommodate new experiences, not just merely receiving and integrating new information as presented by a teacher, but by reconstructing it.

The importance of the constructivist approach to science learning lies in its emphasis on the students' direct experiences with the physical world and its recognition of the active construction of meaning that takes place whenever students interact with their environments.

Within the movement of social constructivism, the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding comes into view (Derry, 1999; McMahon, 1997). Social constructivists view learning as a social process. It does not take place only within an individual, nor is it a passive development of behaviours that are shaped by external forces (McMahon, 1997). Learning is a constructive, socially and culturally situated process. Becoming a central participant in society is not just a matter of acquiring knowledge and skills; it also implies becoming a member of a community of practice.

Many researchers in science education recognise that knowledge is socially constructed (Wellington & Osborne, 2001; Leach & Scott, 2002; Kittleson & Southerland, 2004), and over the last decade, elements of social constructivist conceptions of learning have been used in science education (Frijters, ten Dam, & Rijlaarsdam, 2008; Ogborn, 1997).

In the science classroom, the constructivist view of learning can point towards a number of different teaching practices. In the most general sense, it usually means encouraging students to use active techniques (experiments, real-world problem solving, discussions) to create more knowledge, then to reflect on and discuss what they are doing, and how their understanding is changing.

Within this thesis, five design principles accounting for learning from a social constructivist perspective are explored:

1. Active learning
2. Inquiry-based learning
3. Authentic tasks
4. Reflection
5. Socioscientific issues

These five principles underlie the learning material as examined in chapter 4 and 5. Each of the principles is shortly described here.

1. Active learning

Generally speaking, active learning is a comprehensive term that refers to several models of instruction that focus on the responsibility of learning of the learners. It refers to the processes where students engage in higher-order thinking tasks such as analysis, synthesis, and evaluation. From a social constructivist point of view, the active role of learners is explicitly linked to the processes of making sense. Students are not seen as 'passive receivers' of information but as active interpreters of social meanings (Ogborn, 1997).

2. Inquiry-based learning

An ancient Chinese proverb states: "Tell me and I forget, show me and I remember, involve me and I understand." This adage is the essence of inquiry-based learning. It implies the need of involvement that leads to understanding. Wells (1999) put forward that the class or group should function as a community of inquiry in which each student makes her/his own contribution. Rutherford (1993, p.5) stated that "Hands-on and learning by inquiry are powerful ideas, and we know that engaging students actively (…) pays off in better learning."

3. Authentic tasks

If learning must be meaningful to the individual, it is essential that connections are made between the learning process and situation(s) in which students can and want to apply the knowledge and skills they have acquired. Scientific concepts, as modern biotechnology, should therefore be introduced using issues that are in some way meaningful to students' lives (Goodrum et al., 2001). That is to say, science and technology components should be looked upon from students' perspectives. It helps learners to build bridges between knowledge from formal education to daily live (Grabinger, 1996).

4. Reflection

From a social constructivist perspective, education should aim at learning to participate in society in a critical and aware manner. To increase the quality of participation, reflection is essential. By reflecting on thoughts, feelings and actions, a meaningful picture is created in a student's experience of the world, for which they will take responsibility (Sadler & Zeidler, 2004; Zeidler, Sadler, Simmons, & Howes, 2005; 2002).

5. Socioscientific issues

Issues, such as cloning, stem cell research, genetic testing, and genetically modified foods will play a significant role in 'everyday live'. These are issues that are not only of great importance to scientists; they concern the whole society and can therefore be termed socioscientific issues (SSI) (Kolstø, 2001; Zeidler et al., 2002). The importance of preparing students for decision making on socioscientific issues has been recognised as an important and desired outcome of science education (AAAS,1989; NRC,1996).To empower students as citizens, there is a need to emphasise on this interconnections between science and society and the processes by which scientific knowledge is produced, within the science class.

4. Overview of the studies

With the studies presented in this thesis, we would like to contribute to the development of scientific literacy in the field of modern biotechnology by doing research on attitudes towards modern biotechnology among young people, and science education in this particular field.

As outlined above, the general aim of developing scientific literacy among secondary school students implies that all young people should be able to function effectively in an increasingly complex and technology dependent society. In order to prepare students effectively for responsible future citizenship, it helps to know these students in detail. What attitudes are there among students? What do they know, feel, and want? Therefore, the central questions of this thesis can be phrased as follows: What are the attitudes of secondary school students towards modern biotechnology? How can science education help develop these attitudes to more profound levels?

To answer these questions, two empirical studies have been conducted, each resulting in two chapters.

The focus of the first part of the thesis is on the concept of attitudes

In **Chapter 2**, the concepts of 'attitude' and 'modern biotechnology' and the practice of attitude measurement are discussed. The development of an 'attitude towards about modern biotechnology -questionnaire' and empirical study among Dutch secondary school students is described. We used the tripartite attitude model to explore the attitude components, and examined how they related to each other. Based on the results of the questionnaire four different 'types' of students could be portrayed. The results described in Chapter 2 served as a framework for the subsequent chapters.

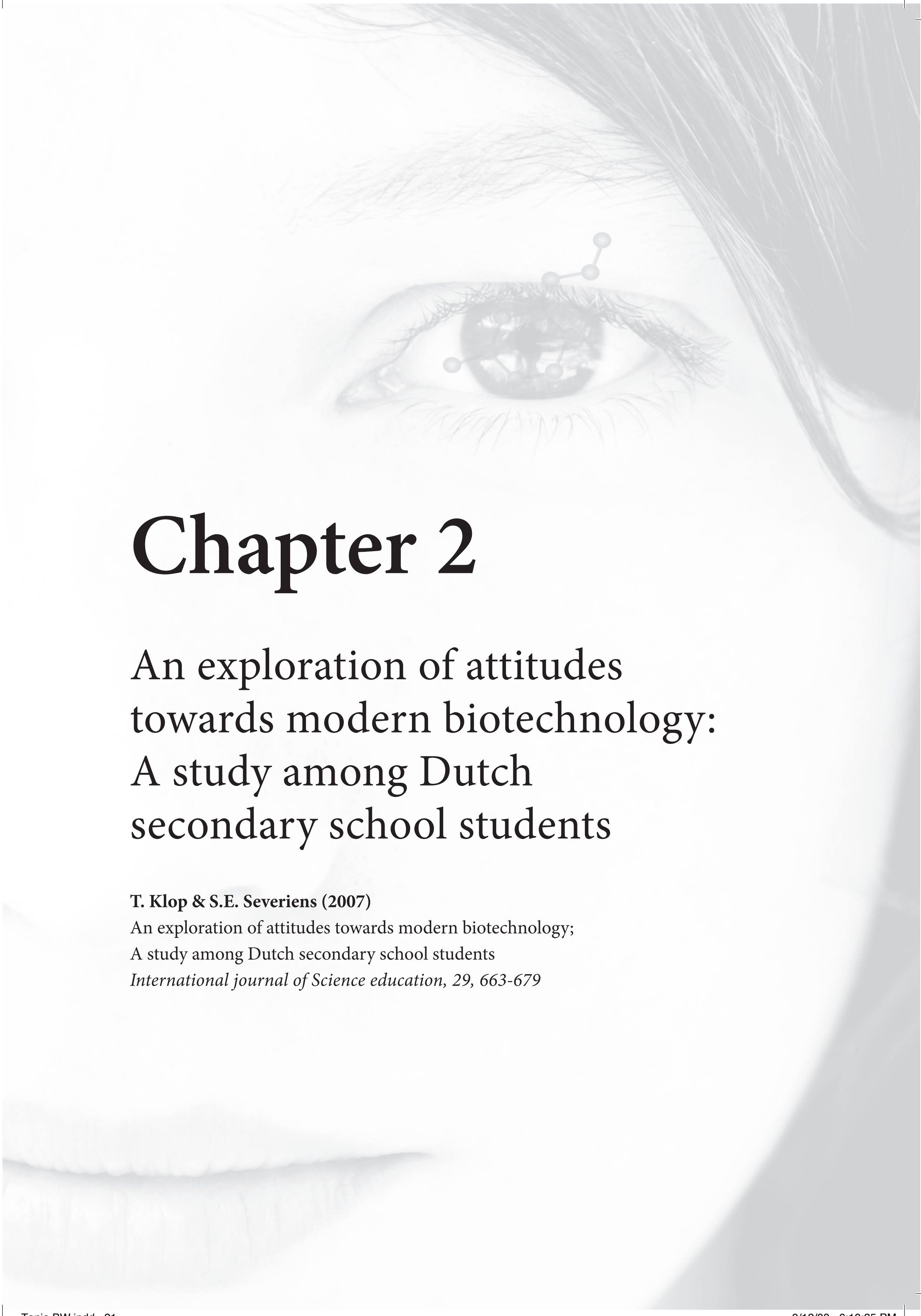
Chapter 3 describes the relationship between these four different attitude groups of secondary school students and their background and value factors associated with attitude towards modern biotechnology. These background factors (such as gender, religious and ethnic background) and value-factors (ethical considerations, benefits/ risks, interest) were also measured in the attitude-questionnaire.

The second part of the thesis is intended to develop a greater understanding of science education aiming to improve scientific literacy among secondary school students. The main question here is to what extent science education can bring about attitudes that are more profound. This link between students' attitudes and classroom practices are essential to examine if we are to understand the impact of science education.

Chapter 4 reports of a quasi-experimental design study (treatment, control groups and pre- and post-tests). The effects of an innovative science education module on students' attitudes towards modern biotechnology (as a measure of scientific literacy) are examined using quantitative methods of research. This science module on a socioscientific subject (cancer and modern biotechnology) consists of several design principles, inspired by a social constructivist perspective on learning.

In **Chapter 5**, a qualitative research method was used to investigate the effects of the science module, as described in Chapter 4, in more detail. This chapter reports on a case study on attitudes and attitude changes towards modern biotechnology of secondary school students. Pre- and post-attitude questionnaires, classroom observations, and pre- and post-module interviews were used to follow students' attitudinal changes.

Finally, **Chapter** 6 provides a summary of the results and general discussion of the findings reported in the studies included in this thesis. In addition, limitation of the studies and implications for future research are closely examined.



Chapter 2

An exploration of attitudes towards modern biotechnology: A study among Dutch secondary school students

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Abstract

Modern biotechnology will have a large impact on society and requires informed decision-making and critical attitudes toward biotechnology among the public. This study aims to explore these attitudes in secondary education.

For this purpose, a questionnaire was constructed according to the general tripartite theory of attitudes. Five-hundred-and four Dutch secondary school students completed the questionnaire.

Based on principal component analyses, several distinct and independent cognitive, affective, and behavioural factors were found, demonstrating that attitudes towards biotechnology are a multi-component concept. In a cluster analysis on these factors, we found four interpretable clusters representing different groups of students. The four groups are labelled as 'confident supporter' (22%), 'not sure' (42%), 'concerned sceptic' (18%) and 'not for me' (17%). These results indicate that there is a diverse appraisal of modern biotechnology amongst secondary school students. Suggestions for educational interventions are made.

1. Introduction

Genomics, the new term for large-scale scientific research on heredity and genes, and its associated technologies (modern biotechnology[1]) are set to become one of the most important scientific and technological revolutions of the 21st century (Kirkpatrick et al., 2002). As such, it is important that the general public understands the main concepts of modern biotechnology. People will need such knowledge in their careers and in their daily lives as members of society to make personal and social choices about issues related to science and technology. In short, it is important that the public becomes more scientific literate in this respect. Our starting point is that science education occupies a central role in the promotion of scientific literacy (Bingle & Gaskell, 1994; Driver, Leach, Millar, & Scott, 1996; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003). When developing an educational strategy, or programme, obviously one must know its 'audience' and consider what understanding modern biotechnology means, and how students arrive at personal and social choices. What kind of arguments do students use in relation to knowledge they may or may not have on the subject? In other words, what different attitudes towards modern biotechnology can be distinguished?

In the next section, we will describe the results of published literature on attitudes of school students towards modern biotechnology within the last 10 years.

1.1. Former research

A small number of studies have examined understanding of secondary school students of, and attitudes towards, modern biotechnology (Dawson & Schibeci, 2003). These studies have investigated students' attitudes towards school science in general (see the review of (Osborne, Simon, & Collins, 2003) or attitudes towards selected biotechnological applications such as genetic engineering of plants (Gunter, Kinderlerer, & Beyleveld, 1998) or attitudes of students towards using genetically engineered animals in medical research (Hill, Stannistreet, O'Sullivan, & Boyes, 1999). However, most of these studies focused on student's knowledge and understanding of biotechnology more than on their attitudes.

The number of studies on attitudes towards biotechnology among the public seems quite substantial, although many of these draw from the so-called Eurobarometer.

This concerns one of the main sources of information on attitudes towards biotechnology (European Commission, 2006). It is an extensive survey on society, science and technology in European countries conducted several times in the past decade. The Eurobarometer includes a number of questions on content knowledge and views among the public regarding different applications of biotechnology. Other studies generally

[1] Biotechnology is a term used to encompass a vast range of techniques for modifying life forms for research (e.g., medical, environmental, agricultural) and commercial uses.

focused on one specific application of biotechnology such as genetically modified foods (GM-foods) (Verdurme & Viaene, 2003) and medical applications and cloning (Balas & Hariharan, 1998). Below, the main studies on attitude towards biotechnology conducted in groups of adults as well as secondary school students will be described. Our review of these studies includes a description of the results in relation to the particular conceptualisation of attitude.

Pardo, Midden and Miller (2002) have described the profile of Europeans' attitudes towards biotechnological applications based on the results of particular questions of the Eurobarometer of 1996. In their article, attitudes were defined as an evaluation of an object based on a cognitive component (information and knowledge about the properties of the object) and an evaluative component (affect and feelings of approval or disapproval toward the object). Pardo et al. expected the public to hold general views on the one hand, as well as more differentiated views regarding specific biotech applications on the other. This means that attitudes towards biotechnology are expected to be fragmentary, especially because it concerns such a complex and developing subject. The Eurobarometer included questions about six specific applications of biotechnology (in the medical as well as food production area), and examined to what extent the respondents find these applications useful, risky, moral acceptable, and whether or not the person would encourage each of the applications. First of all, the results showed that, while some progress in terms of basic scientific knowledge have been made since the Eurobarometer of 1996, the knowledge - and information gap between science and society still exists. Furthermore, attitudes (comprising the perception of usefulness, risk, moral acceptability and encouragement) were somewhat more positive when medical applications are at stake (research and transplants), compared to foods and agricultural applications.

Pardo et al. continued their article by conducting a structural analysis that aimed to explain the perceived benefits and risks. A positive perception of the benefits was predicted by a general technological optimism, a belief in the promise of biotech and being part of an informed public (groups were divided based on a knowledge test, p.11, note 2). The same model, however, failed to predict the perception of risk, suggesting that other factors in the structural model were needed to explain underlying reasons for the public to perceive biotechnology as a risk.

Dawson and Schibeci (2003) have conducted a study among 1116 secondary school students from different Western Australian schools on the understanding of recent advances in modern biotechnology. For this research, a written survey was used to determine their understanding of, and attitudes towards, recent advances in modern biotechnology, such as genetic engineering, cloning and GM-foods.

In this study, attitudes were defined in terms of acceptability of biotechnological procedures. Students indicated whether they thought different procedures were acceptable and clarified their choice. The survey included six questions related to understanding and acceptance of biotechnological applications and procedures.

Approximately one third of the students turned out to have little or no understanding of biotechnology and one third was unable to give a single example of biotechnology. However, there was considerable variation in the understanding of students.

The results on attitude towards biotechnology in a successive study showed that the students hold a wide range of beliefs about what is an acceptable use of biotechnology. The students' responses divided approximately into four groups depending on whether they approved of the use of micro-organisms only, micro-organisms and plants, micro-organisms, plants and animals, or all living organisms. Acceptance of the use of organisms in biotechnology decreases from micro-organisms (>90% approval) to plants (71 - 82%) to humans (42 - 45%) and animals (34 - 40%). Clarification of their statements for acceptance or rejection was rather negative. Arguments such as 'the procedure is wrong', 'unnatural', or 'unethical' were given. Reasons for acceptance were that procedures will benefit humanity or 'if it can be done then it should be done'.

Gunter et al. (1998) examined the understanding and opinion towards biotechnology of 48 teenagers, with special reference to food production. This study was part of a large project designed to investigate public awareness and perception of biotechnology. The results showed that despite these young peoples' poor understanding of biological sciences, they seemed less reluctant towards GM-foods than did adult-respondents. Overall, teenagers considered genetic engineering of plants to be more acceptable than genetic engineering of food crops and animals. Their reasons for opposing genetic engineering of animals was that it is 'unnatural', 'dangerous', 'shouldn't be done' and 'unethical'.

Similar reasons were reported by Hill et al. (1999) who examined the attitudes of 778 students aged 11 - 18 years about using genetically engineered animals in medical research. Forty-two per cent of the sample felt it should not be allowed, because it was cruel (47%), or unnatural (53%). They also found that biology students were less likely to be neutral and more likely to be positive about genetically engineered foods than other students were. While these positive attitudes may be the result of a greater understanding of biotechnology, it could also be argued that the students who have chosen to study biology have a more positive attitude to science than other students do.

From the angle of non-persuasive communication, Verdurne and Viaene (2003) conducted a study on consumer beliefs and attitudes towards GM-foods. Their attitude model included risk and benefit perceptions, which were determined by general attitudes and knowledge about GM-foods. In their interviews with 400 Belgian consumers, they asked about the risk and benefits, awareness and knowledge, attitudes towards science, trust in the government, and beliefs, attitudes and purchase intentions regarding GM-foods. They observed three general factors based on the risk and benefit items: a general health risk factor, a benefit factor, and an environmental risk factor. These three factors clustered into four consumer segments: 'the half-hearted' (34%), 'the green opponents' (16%), 'the balancers' (27%) and 'the enthusiasts' (24%). Several items that combined into one general scale with a high reliability, measured attitudes. Knowledge was measured using the Eurobarometer knowledge items. The results showed that higher levels of knowledge do not necessarily imply greater acceptance of GM-foods.

In summary, looking at these studies suggests that attitudes towards biotechnology do not yet constitute a coherent research area. Some studies defined attitudes in terms of benefits and risks, some defined attitudes in terms of acceptability, and others in terms of a general evaluation. Most studies described a link between understanding or content knowledge and attitudes, but few studies actually investigated this link. Pardo and Calvo (2002) criticised the theoretical underpinning of attitudes towards science (and biotechnology) as measured in the Eurobarometer. They stated that little to no attention was paid to the content of attitudinal items and argued that this leads to conceptual and metrical weakness of scales. The consequence is that empirical support for some published results is very limited (see for an in-depth discussion, Miller, 1998; Pardo & Calvo, 2002, 2004). This seems to be a recurrent issue with research on attitudes. It is not only a complex construct, but a person's attitude seems also incomplete and in a state of evolution, especially in case of extremely complex subjects such as biotechnology (Pardo et al., 2002).

The present study uses the theoretical tripartite model of attitudes (Katz & Stotland, 1959; Rosenberg & Hovland, 1960) as a starting point. This model encompasses three basic attitude components: an affective, a cognitive, and a behavioural component. By choosing this theoretical and empirical strongly underpinned conceptualisation of attitudes, we intend to accommodate the critique of Pardo regarding the generally weak conceptualisation of attitudes towards science. Furthermore, each of the three components is considered as a multi-dimensional component: our conceptualisation of attitudes attempts to uncover different sets of affective, cognitive, and behavioural reactions towards modern biotechnology. By doing this, the present study contributes to research on attitudes towards modern biotechnology by exploring the concept of attitudes in detail.

1.2. The attitude model in the present study

In general, an attitude can be described as a summary evaluation depicting favourable or unfavourable feelings towards a specific or psychological object (Ajzen & Fishbein, 2000; Eagly & Chaiken, 1993; Weinburgh & Engelhard, 1994; Zacharia, 2003). In the present study the object is modern biotechnology, in specific the associated technologies of genomics. According to the tripartite theory of attitudes, attitudinal responses can be classified into three general components; an affective, a cognitive, and a behavioural component (Breckler, 1984; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960). The cognitive as well as the affective component influence evaluations, which in turn affect behavioural intentions (Ajzen, 2001; Heijs et al., 1993; Tesser & Shaffer, 1990). In the cognitive component, the evaluation of modern biotechnology follows from beliefs, thoughts, and knowledge of the object. The affective component of attitudes reflects how students feel about genomics, for instance anxieties and fears about this contemporary technology. Furthermore, attitude is one of the important determinants of intentions and behaviour, for example consumption or protest (theory of planned behaviour) (Ajzen & Fishbein, 2000; Armitage & Conner, 2001; Zacharia, 2003).

1.3. Research questions

The concept of attitude includes levels of knowledge as well as cognitive and affective evaluations and behavioural intentions. In the following quantitative study, each of the components of the tripartite attitude model will be explored and related to each other. Therefore, the following three research questions can be formulated:

1. *Which kind of cognitive, affective evaluations and behavioural intentions can be observed?*
2. *How do these attitude components interrelate?*
3. *Can different attitude patterns of secondary school students be distinguished?*

2. Method

The main aim of this study is the exploration of secondary school students' attitudes towards modern biotechnology in more detail. For this purpose an instrument (questionnaire) was designed which measures the various attitude components in relation to content knowledge and different areas of modern biotechnology.

2.1. Participants

Based on a list of all Dutch schools in four large cities in the western part of the Netherlands, teachers were invited to participate with their students. A total of 47 schools were approached, of which thirteen consented to participate with one or more of their classes of sixteen-year-old students.

In the Netherlands, the secondary education system for pupils aged between twelve and eighteen years is divided into three main levels: secondary vocational education (VMBO, 12-16 years), general secondary education (HAVO, 12-17 years), and pre-university secondary education (VWO, 12-18 years). A total sample of 634 secondary school students of all three main school levels took part in the study.

Students were excluded from subsequent analysis if they completed less than 33.3% of the questionnaire or showed a 'suspicious' answer-pattern, e.g. all questions were responded to in identical fashion, or included contradictions. This resulted in a dataset of

574 respondents, 147 from VMBO[2] (25.6%), 147 from HAVO (25.6%), 280 from VWO (48.8%), with 262 males (45.6%) and 312 females (54.4%). Focus was on sixteen-year-old students (average age = 15.8 year, SD = 0.66).

2.2. Design of instrument

The questionnaire was designed based on two sources: a variety of existing surveys and a small-scale qualitative research study.

A literature search regarding possible surveys resulted in a number of instruments of which items could be used for the purpose of the present study, including surveys on attitude towards science. The most important of these are the Eurobarometer (European Commission, 2001), the instrument of Heijs (Heijs et al., 1993) and the International Bioethics Survey Questionnaire. One or more items or ideas have been taken from other surveys[3].

The qualitative study consisted of six group discussions with four different sixteen-year-old students (from all three main educational levels) and thirteen in-depth interviews with researchers in the field of genomics.

In the group discussions, the students were questioned about their knowledge and understanding of biology, genetics and modern biotechnology, their feelings towards several applications of biotechnology, and behavioural intentions towards biotechnology. The students were also asked to elaborate their perception of risk associated with biotechnology, their ethics and beliefs, and their own experience and interest. Discussions with the students were tape-recorded and the responses were transcribed verbatim and analysed afterwards. Each interview lasted approximately fifty minutes.

The qualitative study among students served two goals. First of all, the open-ended questions uncovered the cognitive and affective base of attitude in detail. This is an important condition to arrive at construct validity of the instrument.

Secondly, the interviews with students were also used to adapt the used language in the existing instruments. This adaptation was needed because these instruments generally aim at adults.

The interviews with genomics researchers resulted in an overview of modern biotechnology. In accordance with existing instruments, the objects have been classified as follows: agriculture (plants, food industry), livestock (animals, animal experiments, and food industry), medical science (medicines, diagnostics, and treatments), industry (micro-organisms) and legislation.

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2 The group of students in the pre-vocational tracks are underrepresented (in Dutch educational system nearly 60% of secondary school students are in this track), and the coverage of the region is not equally spread.

3 Centre for Consumer & Biotechnology, 2002; Human Genetics Commission, 2000; Princeton Survey Research Associates, 2002.

2.3. The instrument

The first section of the instrument was designed to obtain (socio-) demographic information about the students. The second and third part of the instruments includes four categories of items: knowledge items, cognitive evaluation items (beliefs), affective evaluation items, and behavioural intention items.

- *Knowledge items*

In the second section, the cognitive component of attitude towards biotechnology was measured through 47 true-false items (bivariate items). In this instrument, the items cover relevant school-subjects in the field of biotechnology: biology and genetics, and technology and science. Students should (or could) have learnt about these subjects in school or from popular science programmes or magazines. Some items cover the existing misconceptions about modern biotechnologies. Incorrect answers on these items reflect not only lack of scientific knowledge (textbook knowledge) but also a tendency to associate biotechnology with several existing inaccuracies (European Commission, 2001).

- *Cognitive and affective evaluation items*

The third section asked students about their cognitive and affective evaluation about biotechnology. The affective evaluation is measured by 28 Likert-type items, represented by questions concerning negative and positive feelings and emotions towards different aspects of modern biotechnology. Thirteen items on cognitive evaluation tried to capture beliefs, expectancies, and perceptions of modern biotechnology.

- *Behavioural intention items*

The third section also measured the behavioural intentions (20 Likert-type items). Since secondary school students usually have not encountered many contexts in which they had to act or make a decision regarding biotech issues, we decided to measure behavioural intentions as a proxy for actual behaviour. These intentions were examined by outlining situations in which one will or will not act (protest against genetic modification of crop), buy (jeans made of genetically modified cotton), or use (genetic screening).

The items from the third section were measured by five ordinal categories ranging from 'strongly disagree to strongly agree' (Becker & Maunsaiyat, 2002). Together, the second and third sections of the instrument measured the basic components of attitude.

- *Fourth section*

The questionnaire continues with explanatory factors: students' ethical opinions (number of items is 45), their interest in biotech (n = 10), source of information and school factors (n = 9), benefits and risk of biotechnology (n = 35), self-perception of own opinion (n = 13) and trust in biotechnology and different institutes. In a subsequent article, the results of these explanatory factors will be described, together with the relationships between background variables and attitude.

2.4. Administration

In the period from February through April 2004, teachers administered an on-line version of the questionnaire during a regular class. In this way, the questionnaire could be answered immediately, and the response rate of the students was 100%. Either the teacher or the researcher gave the students instructions.

2.5. Analyses

Data were analysed by means of the Statistical Package for Social Sciences software, version 12.0.1 (SPSS). The analyses were conducted in two steps: 1) scaling of attitudinal factors and 2) exploring subgroups of students sharing similar 'attitudinal values'.

In the first step of scaling, factor analyses (principal component analyses with varimax rotation) and reliability analyses are used to arrive at underlying structures of the three main components of attitude.

Subsequently, the items loading high on the 'interpretable' factors are analysed in reliability analysis. To arrive at scales with sufficient reliability, items with low item-total correlation were removed from the scale and excluded from further analysis. This was done only in those instances where the content of the scale was not jeopardised.

In the second step, K-means cluster analysis using Euclidean distance was performed on the attitudinal scales. K-means cluster analysis is a statistical method for finding subgroups of individuals who share similar 'values' on a set of variables, builds group clusters by finding cluster centres on values of variables and assigning cases to the cluster that produce the best-fit model.

3. Results

First, we present the results of the factor analyses.

Content knowledge

The item pool consisted of 47 true-false statements intended to cover, as broadly and as relevantly possible, school-topics of biotechnology and genetics. The mean score for the whole sample was 34.02 (SD = 5.33).

We constructed the scales based on a priori classification of the items (according to the contents of the Dutch secondary biology education), namely 1) biology and genetics and 2) biotechnology and its applications.

Although the items loading high on the first factor resulted in a scale with a Cronbach's alpha of 0.63 (borderline), it was clearly interpretable and we decided to accept it as a scale (n = 9). The second factor resulted in a reliable scale with an alpha of 0.71 (n = 17) (Table 1).

Cognitive evaluation, beliefs

The questionnaire included 11 items that aimed to evaluate attributes of genomics. An exploratory factor analysis was conducted on the responses to the 11-evaluation items. Principal components analysis with varimax rotation (PCA: VR) was initially performed without specifying the number of factors to extract, since there was no expected factor structure. Factor analysis showed that the best result was a one-factor solution with five items on beliefs about biotech (explained variance is 26.1%). Reliability analysis confirmed this finding with an alpha of 0.70 (Table 1). Apparently, students group all 'cognitive attributes' on one dimension. They are either positive or negative about the different genomics attributes.

Affective evaluation

Also on the responses to 29-affect items, an exploratory factor analysis was conducted, without specifying the number of factors to extract. A solution with three factors (in total 27 items) turned out to be interpretable. The three factors explained 38.4% of the variance. The first factor indicated a basic emotional reaction to biotechnology, such as being scared or excited. The second factor indicated feelings of biotechnology as an unavoidable process ('it is going to happen anyway'). The third factor indicated a worried stance, or a feeling of unease regarding biotech developments.

A reliability analysis confirmed this finding. The items showing high factor loadings were included in reliability analyses, which resulted in three reliable scales as shown in Table 1.

Behavioural intentions

As mentioned before, the decision was made to incorporate questions regarding students' behavioural intentions only. A total of 20 items was included, and three factors, which explained 58.6% of variance, were extracted. The first interpretable factor ($\alpha = 0.78$) covered intentions of consuming when there is a personal benefit to gain, for instance when genetically modified (GM) products are cheaper or contain less fat. The second factor included medical intentions, such as undergoing genetic tests, and resulted in a reliable scale of $\alpha = 0.74$. The third factor also included consuming intention, but under critical or environmental conditions (e.g. environmentally friendlier). This factor resulted in a scale with a Cronbach's alpha of 0.74 (Table 1)

3.1. Clustering of students

Finally, the whole dataset was subjected to a K-means cluster analysis using Euclidean distance. In this step, we investigated whether subgroups could be identified within the whole group of students. Cluster analysis was used to examine these subgroups. Because of the exploratory nature of these analyses, different numbers of clusters were analysed.

Table 1. Attitude factors with scale name, description, typical items, reliability and descriptive values, based on principal component analyses

Attitude components	Attitude factors	Description	Typical item	Cronbach's alpha (No. of items)	Mean (SD)
Cognitive component	Biology and genetics*	Knowledge of biology and genetics	DNA contains the information for all you hereditary factors.	0.63 (n = 9)	7.10 (1.8)
	Biotech*	Knowledge of biotech applications	Normal tomatoes have, in contrast to GM tomatoes, no genes.	0.71(n = 17)	13.80 (1.8)
	Beliefs	Evaluative knowledge of biotech / beliefs about biotech	I think genomics can solve food problems in the third world	0.70(n = 5)	3.09 (0.64)
Affective component	Basic emotion	Basic emotional reactions	Genetic modification (GM) is bad.	0.78 (n = 13)	3.00 (0.58)
	Unavoidable	Feelings of biotech being unavoidable	Biotechnology is absolutely necessary.	0.76 (n = 9)	3.12 (0.62)
	Worries	Worries about biotech	How many worries do you have about genetic research?	0.79 (n = 5)	2.97 (0.79)
Behavioural component	Own intentions	Consuming intentions; own interest	I would eat GM food if it was cheaper than normal food.	0.78 (n = 5)	3.09 (0.82)
	Medical intentions	Medical intentions	Would you take a genetic test during your pregnancy?	0.74 (n = 4)	3.10 (0.83)
	Critical intentions	Consuming intentions; critical conditions	I would buy GM food if it were grown more environment-friendly than normal food.	0.74 (n = 3)	3.60 (0.90)

*bivariate data

An analysis with four clusters led to interpretable and interesting groups with sufficient numbers of students. Figure 1 portrays the factor scores in each of the four clusters.

Confident supporter (cluster 1)

Positive, pro-biotechnology and well educated in science, the 'confident supporter' (130 students, 22.6% of the respondents) seems to welcome biotechnology in their daily lives. Not only do they hold great expectations for the future, they are enthusiastic and have no worries. They tend to be confident about their future intentions of "becoming a consumer of biotech- products", from eating genetic modified foods to taking genetic tests during pregnancy (see Figure 1).

Not Sure (cluster 2)

This group of 239 students (41.6%) forms the largest group of students. Their views tend to be quite indistinct: they are neither 'anti-biotechnology nor pro-biotechnology'. The students in the 'not sure' group have a reasonable knowledge base and hold positive beliefs about biotechnology but are sceptical when it comes to their 'gut-feelings'

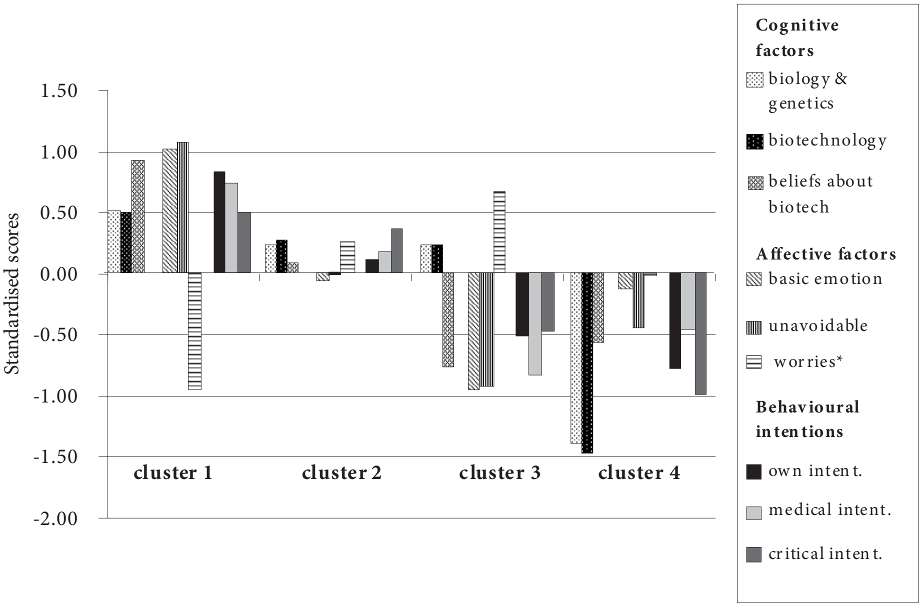


Figure 1. Results of k-means cluster analysis of 574 secondary school students' attitudes towards modern biotechnology, using a user-defined cluster number of four
Cluster 1: confident supporter cluster (n = 130); cluster 2: not sure cluster (n = 239); cluster 3: concerned sceptic cluster (n = 105); cluster 4: not for me cluster (n = 100). Scores on the different factors of the three main attitudinal components are standardised values.*Negative score on 'worries-factor' indicates fewer worries about modern biotechnology.

(basic-emotions). There is also quite some concern about biotechnological developments. However, their negative affection, does not stop them from having intentions towards consuming biotech products, especially not if critical or environmental conditions are met. They also seem to appreciate its applications in the medical world (see Figure 1).

Concerned sceptic (cluster 3)

This well-informed group of 105 students (18.3%) tends to be very sceptical and concerned about biotechnology. They hold sceptical beliefs towards biotechnology, seem to be scared, and concerned of what modern biotechnology will bring. They fear the impact on nature and do not see it as 'a natural evolvement' of the current society. The 'concerned sceptics' do not intend to have anything to do with it now or in the future, especially not in the medical field (see Figure 1).

Not for me (cluster 4)

This group consists out of 100 students (17.4% of the total), and is thereby the smallest group. They are very negative when it comes to biotechnology. They hold very little knowledge about the subject, and their beliefs about biotechnology are very negative. This group of students is less pronounced in their affective reactions. On the other hand, they are very explicit in their behavioural intentions. This 'not for me' group shows no intentions of ever buying, eating or using anything made from or with modern biotechnology. Only the intention towards the medical field is a little less negative (see Figure 1).

4. Conclusions

In the present study, the tripartite attitude model was used to explore the concept of attitude towards biotechnology in all its features. In this section, the results will be summarised and compared to former research. Some conclusions will be drawn and the major implications for further research will be presented.

The results show that attitude towards biotechnology is a multi-component concept of various cognitive, affective, and behavioural features. Different types of affective and cognitive evaluations, two different types of content knowledge and three different types of behavioural intentions interact and result in a specific set of four attitude patterns.

The **cognitive component** consists of a combination of content knowledge and a cognitive evaluation. The results confirm two different types of knowledge on modern biotechnology. The first type concerns content knowledge on biology and genetics, referring to the basic concepts in this discipline. The second type concerns knowledge and understanding of biotechnology applications. Cognitive evaluation refers to beliefs, expectancies, and perceptions related to modern biotechnology.

Except for the 'not for me'-group of students the respondents in this study show reasonable to very good content knowledge. This is quite different from the most common findings in content knowledge towards biotechnology, which imply limited understanding of concepts and implications of modern biotechnology (Dawson & Schibeci, 2003; Osborne et al., 2003). It is possible our study confirms the observed progress in terms of basic scientific knowledge since the Eurobarometer of 1996 (Pardo & Calvo, 2002). On the other hand, the cognitive evaluation (beliefs and expectancies) of biotechnology seems rather negative. Especially the 'concerned sceptics' and the 'not for me' groups evaluate the attributes of biotechnology in a negative sense. The 'confident supporters' with the highest level of content knowledge are also most positive about the attributes of biotechnology. However, this link between content knowledge and cognitive evaluation only emerges in this group of supporters. In the other groups, content knowledge does not seem to relate to cognitive evaluation. This is shown for example by the fact that the 'not sure' group and the 'concerned sceptics' do not differ in terms of their knowledge, but they do differ in terms of their cognitive evaluation. These finding shows the complex nature of the relationship between content knowledge and attitude towards biotechnology. Although in general one may conclude that more content knowledge is related to more positive cognitive evaluations, it also depends on other aspects of attitude patterns such as affective evaluation and behavioural intentions.

In the **affective component**, three types of evaluations emerge. The first evaluation can be described as a basic emotional reaction, the second reaction expresses feelings of unavoidability, and the third revolves around worries. Students with clear positive basic emotional reactions can be found in the group of 'confident supporters'. The 'concerned sceptics' on the other hand seem to disagree with the stance of 'it is going to happen anyway' combined with high level of concern and unease regarding biotechnology. The remaining two clusters are less pronounced in their affective evaluations of biotechnology. As described in the introduction, other research on the affective component of attitude often describes attitude in terms of a single dimension: individuals either oppose or favour biotechnology. Our study has clearly shown that the way people feel about biotechnology is a more complex issue.

The **behavioural component** is indicated by three types of intentions: 1) an intention to consume because it serves one's own interests, 2) an intention to co-operate if it serves medical purposes, and 3) an intention to consume if certain conditions are met, for example, environmental issues. All groups seem to have different kinds or combinations of intentions. For the 'confident supporter' group the dominant intention is to consume when it is in one owns interests. For the 'not sure' group critical conditions seem most important for deciding whether to become involved with applications of biotechnology.

Both the 'not for me' group and the group of 'concerned sceptics' do not seem likely to engage with biotechnology at all. A difference between the two groups is that the 'concerned sceptics' show no intentions to make use of medical applications, whereas the 'not for me' group seems less reluctant to, for example, take a genetic test when pregnant.

The results of the Eurobarometer suggest that most European adults are supportive of biomedical use of biotech. This is only in part confirmed by our results: the confident supporters do seem to intend to engage with biomedical applications, but the remaining groups are more reluctant.

In summary, the findings in our study confirm what is frequently assumed and emphasised in studies on attitudes towards biotechnology (or science in general), namely that the more one knows about the subject, the more positive one's feelings and the more positive the behavioural intentions. This relationship between the three attitudinal components is observed in the comparison of the 'confident supporters' versus the 'not for me' group. Nevertheless, this study also shows that in the largest group of students ('not sure' and 'concerned sceptics'), a different pattern of relationship among the three attitude components emerges. In these two largest groups, a reasonable to good cognitive basis combines with negative or neutral affective responses and behaviour intentions. These results clarify that with respect to a complex subject such as modern biotechnology, each of the attitude components has its unique contribution to the overall attitude.

One of the starting-points of our study was Pardo's argument about the necessity to include a broad range of dimensions in 'modern biotechnology' and its implications, e.g. predictive medicine, genetically modified food and cloning. All these dimensions are important in showing what attitudes towards biotechnology bring about (Pardo et al., 2002). We tried to cover most of these relevant dimensions in our conceptualisation of attitude towards biotechnology. However, the results of the study by Verdurne and Viaene (2003) on consumer beliefs and attitude towards GM-foods are rather similar to our four clusters. This seems to imply that the public seems to react with similar attitudinal patterns when GM-foods are considered, compared to when a broad range of biotech applications are considered.

We have stated that research on attitudes towards modern biotechnology is important given its expected impact on society. Citizens must be capable to make informed decisions about issues affecting their own lives in the near future. They also should have the opportunity to participate in decision-making processes based on a basic level of understanding socially relevant developments in this field of science. In the light of these scientific literacy goals, education is an important factor. Detailed information on what an attitude towards modern biotechnology entails may serve as a basis for designing good quality education. Our study has clearly shown that the way students think feel and intent to act with biotechnology is a complex issue.

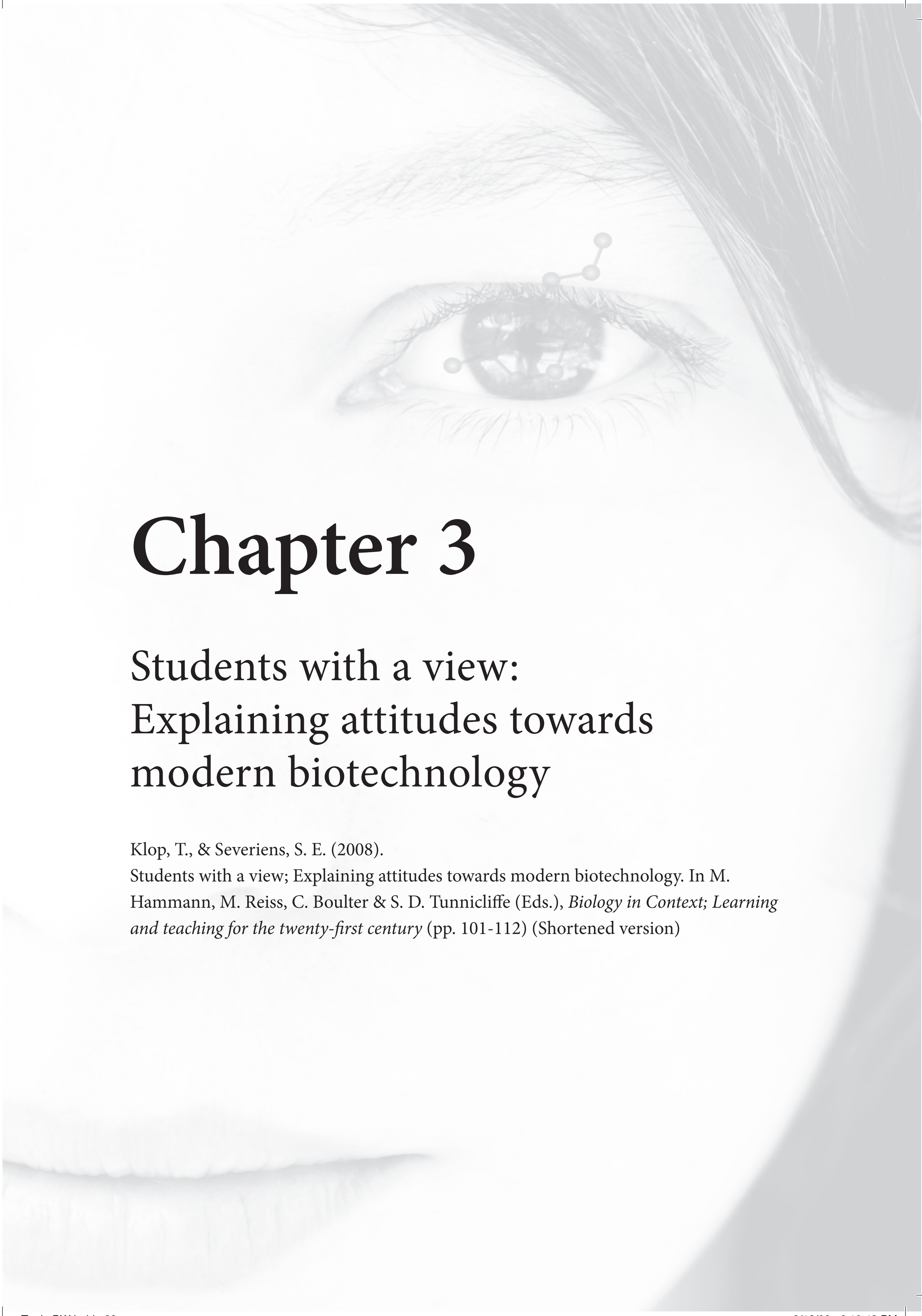
4.1. Future research

The isolation of a person actual attitude is rather tricky since that person's attitude is always incomplete and in a state of evolution, especially when they deal with extremely complex subjects such as biotechnology is (Campbell, Converse, Miller, & Stokes, 1976; Pardo et al., 2002). This has always been a problem for measuring a complex construct as attitude is. For this reason, it is important to replicate the present study in a large and truly random sample of Dutch secondary school students. Furthermore, a replication in a sample drawn from the public would improve the possibility of generalization even more. In such a sample, it would also be possible to examine the validity of the questionnaire, for example by including actual behavioural measures.

A second line of future research concerns the research question on how attitudes patterns towards biotechnology can be explained. General scientific interest may play a role, as well as beliefs regarding science and technology, but also moral beliefs may explain why students hold certain attitudes (Osborne et al., 2003; Schibeci & Riley, 1986). A number of studies have found several background factors that influence the attitudes people hold (Ajzen & Fishbein, 2000; Atwater & Simpson, 1984). Important background factors are personal characteristics, such as religious background, ethnicity, educational level, and gender. It is interesting to examine whether group differences emerge in the concept of attitude as defined in our present study.

4.2. Implications for science teaching and communication

Although limitations have to be taken into account, the findings of this study highlight issues that may have to be considered by curriculum planners and science teachers who wish to incorporate scientific literacy into science curricula. When educating students about modern biotechnology and its implications, one has to keep in mind that students hold different starting points when considering modern biotechnology. Not only should science education focus on knowledge and understanding, but also on the affective side of biotechnology. This change in emphasis might help students to create a more balanced attitude towards biotechnology. These findings should be taken into account in the development of educational programmes for secondary school students on informed decision-making towards modern biotechnology.



Chapter 3

Students with a view: Explaining attitudes towards modern biotechnology

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Abstract

The present study investigates background factors and student ethical values and opinions associated with secondary school students' attitudes towards modern biotechnology. Five-hundred-and-four students completed a detailed questionnaire on attitudes and associated factors. Descriptive and multinomial logistic regression analyses were conducted to examine the relationships between different attitudes secondary school students hold, and their background and value factors.

Results showed that there was a significant relationship between educational level, ethical perceptions regarding several applications of biotechnology, and perceptions of benefit on the one hand, and attitude towards modern biotechnology on the other hand. Students with more developed attitudes, often stemmed from higher educational levels, held more outspoken ethical point of views (positive or negative), and considered the development in modern biotechnology more often to be beneficiary, than did students with poorly developed attitudes. Implications for science education and future research are discussed.

1. Introduction

Genomics, the general term for scientific research on heredity and genes, and its associated technologies (modern biotechnology) are set to become one of the most important scientific and technological revolutions of the 21st century (Kirkpatrick et al., 2002). As such, it is important that the public understands the main concepts behind modern biotechnology. One should understand how modern biotechnology and society influence one another, and should be able to use this in everyday decision-making.

Socio-scientific issues, such as cloning, stem cell research, genetic testing, and genetically modified foods will have a significant effect on everyday live. For this reason, it has been recognised that science education must provide pupils with insight into some of the challenging ethical and moral decisions that have to be made about new technologies and how we should apply them (Waarlo et al., 2002). Students should develop profound attitudes needed to become responsible human beings, to be able to think for themselves and to function effectively in an increasing complex and technology dependent society. The term that best describes this overall purpose of the science education is developing scientific literacy (Millar, 2006; OECD, 2006). In a previous study (Klop & Severiens, 2007), we found that students' attitudes play a significant role in their values, interest and response to modern biotechnology in general and to issues that affect them particular.

Several studies suggested that secondary school students have a limited interest in and understanding of concepts and implications of modern biotechnology (Dawson & Schibeci, 2003; Gunter et al., 1998; Macer, 1992). Furthermore, in a previous study, we have demonstrated that the largest percentage of students hold rather poorly developed opinions (Klop & Severiens, 2007). In the present paper, we describe a study that complements this previous work on attitudes towards biotechnology of Dutch secondary school students. The goal is to explore in further detail why most students are unsure about what to think of modern biotechnology, whereas other students are more outspoken. What kind of secondary school students arrive at certain attitudes towards, and how do ethical values about biotechnology relate to attitude? The present study contributes to the state of the art regarding the basic attitudinal constructs of scientific literacy towards modern biotechnology by relating overall attitudes to the main background factors and value factors. This insight will provide input for potentially successful education in biotechnology. As Simpson et al. (1994) argued: 'attitudinal indicators are an essential component in determining the state of science education.'

As the present study complements our former study, we will firstly summarise our previous work and secondly describe the main attitudinal indicators we identified.

1.1. Attitudes towards modern biotechnology

In general, an attitude can be described as 'a summary of evaluations, representing favourable or unfavourable feelings towards a specific or psychological object' (Ajzen & Fishbein, 2000; Eagly & Chaiken, 1993; Weinburgh & Engelhard, 1994; Zacharia, 2003). In this case, the object is modern biotechnology. The definition of attitude is based on the theoretical tripartite model of attitude (Breckler, 1984; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960). This model encompasses three basic attitude components: an affective, a cognitive, and a behavioural component. These components can be described as follows:

- In the cognitive component, the evaluation of modern biotechnology follows from beliefs, thoughts, and (previous) knowledge of the object.
- The affective component of attitudes reflects how students feel about genomics, for instance anxieties and fears about this contemporary technology.
- The behavioural component is described based on behavioural intentions as a proxy for actual behaviour. Behavioural intentions can be depicted by outlining situations in which one does or does not act (protest against genetic modification of crop), buy (jeans made of genetically modified cotton) or use (genetic screening).

1.2. Previous research

Based on the theoretical tripartite model, a small-scale interview study and questionnaires used in former research (among others, Balas & Hariharan, 1998; European Commission, 2006; Verdurme & Viaene, 2003), an attitude instrument was developed and tested in a pilot study. A sample of 574 Dutch secondary school students was asked to answer the revised questionnaire in order to determine their attitudes (Klop & Severiens, 2007).

Based on principal component analyses, a set of several independent underlying factors within the affective, cognitive and behavioural components were found (see Table 1 for descriptions). In a subsequent cluster analysis, four interpretable attitude-clusters based on that set of factors could be described, representing four different groups of students (attitude clusters). The four groups were labelled as:

- 'Confident supporter' (22%). The 'confident-supporters' were a positive, pro-biotechnology and well-informed group of students, who seemed to welcome biotechnology in their daily lives. We can call this group well scientifically literate.
- 'Concerned sceptic' (18%). The 'concerned sceptics' also represented a knowledgeable group of students, except they displayed affective reactions of concern and tended to be very sceptical about biotechnology. This group students had profound attitudes, and could also be called good scientifically literate.
- 'Not for me' (17%). The smallest group, the 'not for me' students, was rather negative about biotechnology. They had poor knowledge of the subject and their beliefs and affective reactions were very negative. Their scientific literacy level is rather low.

- 'Not sure' (42%). The last cluster, the so-called 'not sure' group, formed the largest group. Their views tended to be rather unclear, they were not sure what to think, feel, or do with modern biotechnology and their overall knowledge of the subject left something to be desired, just as their level of scientific literacy (Klop & Severiens, 2007).

In the next section, an overview is given of relevant variables with possible impact on attitudes. Based on former research on attitudes (of secondary school students) towards biotechnology or science, and existing surveys on the subject, a distinction is made between background factors on the one hand and value factors on the other hand.

1.3. Students' background factors and attitude towards modern biotechnology

Gender

Several researchers have examined gender differences in students' general attitudes toward science and have consistently found that boys have more favourable attitudes toward science then do girls (Hill, Stanisstreet, Boyes, & O'Sullivan, 1998; Jones, Howe, & Rua, 2000; Kotte, 1992; OECD, 2007). Most studies on gender differences have focused on differences in cognitive factors or differences in interest (Neathery, 1997; Schibeci & Riley, 1986). Research by, for instance, the American Association of University Women (1992), revealed that although female students received equal, or sometimes better, grades in science courses, the females showed less interest in science subjects than male students did. Several factors related to gender-differences have been described, for example, the fact that science has historically been and still is a male dominated and orientated profession (Miller, Slawinski Blessing, & Schwartz, 2006). Kahle found in her examination of data from the National Assessment of Educational Progress (NAEP), that girls described their science classes as 'facts to memorize', and 'boring' (Kahle & Lakes, 1983).

Although in recent years boys' performance on science achievement-tests were no longer higher on certain standardised tests (National Science Board, 2002), girls' perception of science still differs from those of males. Girls perceive their academic strength to be in verbal areas, whereas boys perceived theirs to be in mathematics and science and more often choose the science subjects and following studies (Archer & McDonald, 1991; Hykle, 1993; Miller et al., 2006; Olszewski-Kubilius & Turner, 2002). These perceptions result in a large under-representation of girls in science, and of women in science and technology (e.g. recent analyses of the Dutch Council for Work and Income, 2005). Based on these findings regarding gender differences in science achievement, and general attitudes towards science, gender differences may be expected in attitudes towards biotechnology as well.

Religious background

The role of students' religious backgrounds has not often been investigated in this field of research on attitudes. This omission is odd, given the fact that in all large cities in Western Europe large percentages of people stem from a variety of religious cultures. Several educational studies have shown the impact of an individual's religious beliefs on their acceptance of standard scientific theoretical models such as biological evolution (Ayala, 2000; Cobern, 1994; Smith, 1994). Therefore, it is not unthinkable that ideas about biotechnological issues (meddling with life, playing God) also differ according to religious background.

Articles that frequently appear in religious publications express concerns about interfering with genes (Nelkin, 2004). Experiments in gene therapy and genetic engineering have brought objections from the Christian community, convinced that scientists are playing God, tampering with God's will, and touching on immortality. Other religions, including most sects of Judaism and Islam, have no objection to, for example, stem cell research. Within these religions, the early embryo is not considered to be fully human (Reichhardt, Cyranoski, & Schiermeier, 2004). On the other hand, religious values attached to animals in case of transplantations or transgenic animals (however far-fetched and scientifically impossible) may also influence attitudes towards biotechnology. For this reason, we decided to include religion as background factor as well.

Ethnic background

The National Science Foundation (2004) observed differences in achievement within science courses by ethnicity. They found that not only women, but also minorities groups as, African-Americans and Hispanics took fewer science courses in high school; earning fewer bachelors, masters, and doctoral degrees in science and engineering; and were less likely to be employed in science and engineering than were white males. The OECD-PISA 2006 reports that although an important subgroup of migrants is highly skilled, many have low skills and are socially disadvantaged. Such disadvantage, along with cultural and ethnic differences, may also create academic disadvantaged, either because they are immigrants entering a new education system or because they need to learn a new language in a home environment that may not facilitate this learning (OECD, 2007) .

Since a large percentage of the Dutch pupils stem from other than native Dutch backgrounds, this could be an indicator for students having different views towards biotechnology. As socio-economic status (SES) and ethnic background are often linked, i.e. ethnic family backgrounds are more frequently from low SES backgrounds (CBS, 2003), SES was incorporated in this questionnaire as well. There is mixed evidence however, in the study of Butler (1999) neither ethnic background nor SES turned out to be a significant predictor of students' intentions to perform science learning activities.

Personal experience

People with a genetic disease or people related to someone with a genetic disease possibly have a different view towards (medical) biotechnological issues compared to people with no such familiarity. Apart from the possible positive or negative experience of medical possibilities, another reason for a different view is that personal experiences can be a source of knowledge. It is known that an attitude will or can be more outspoken when the attitude is important to oneself or those close to you and when the attitude is based on personal experience (Eagly & Chaiken, 1993). Therefore, people with a genetic disease or those who are related to someone with a genetic disease possibly have a different attitude towards medical biotech issues compared to people with no familiarity with this subject.

Level of education and achievement

Level of education has a significant impact on attitude (Zacharia & Barton, 2004). It has been shown to be related to both scientific literacy and to attitudes towards science and technology (Gaskell et al., 2003; Pardo et al., 2002). Compared to students with a lower education-level; students with a higher level of education have a more extensive knowledge base available which can affect their attitude towards biotechnology (Cannon & Simpson, 1985). Besides, Rennie and Punch (1991) found a positive correlation between grade level and achievement and attitude towards science. There also seems to be a correlation between positive attitudes towards science and high achievement in science classes (higher marks) (Cannon & Simpson, 1985). Because of these relationships between level of education and science achievement on general attitudes towards science, we may expect to find a positive connection between level of education and achievement and attitude towards biotechnology on the other hand.

1.4. Value factors

Besides the background factors, there may be several 'value' and 'interest' factors that relate to attitude towards biotechnology. These factors should not be confused with one of the three attitude components in the tripartite model. Conceptually, we consider these factors to be antecedents of attitude.

Ethical considerations

Issues, such as cloning, stem cell research and the genetically modification of food, require thinking about ethical issues. Examples of ethical considerations are whether one should allow biotechnology applications in medical therapy, modify life forms for research (medical, environmental, agricultural) or allow biotechnology applications for commercial use. The answers to these questions may be a key factor in attitudes towards biotechnology (among others Gaskell et al., 2003; Macer, 1994). Considering the ethical implications is an important step in making decisions regarding socio-scientific topics such as modern biotechnology (Evans, 2002; Sadler, 2004). The same may be true for arriving at well-founded attitudes towards biotechnology. Dimopoulos and Koulaidis (2003) argued that biotechnological issues with possible impact on the society are often groundbreaking and therefore go together with uncertainties, making these issues sensitive to related social pressures and thereby value-laden. How one evaluates the ethical aspects in this field of research, can therefore have an important impact in the formation of an attitude towards biotechnology as a whole (Gaskell et al., 2003; Macer, 1994). On the basis of outcomes in these former studies, the present study will investigate the relationship between students' views regarding basic ethical questions, such as 'is it always allowed to use biotechnology?' and their attitude towards biotechnology.

Benefit and risk

The perception of benefits and risks has a direct influence on the eventual attitude towards biotechnology according to several studies (Pardo et al., 2002; Pifer, 1996). Generally, if the risks are perceived as high, the attitude will be more negative. For many people the idea of genetically tampered food is perceived as highly threatening for health and safety (Gunter et al., 1998). This presupposition often goes together with a poor understanding of what the technology entails Moreover, people with more or less education or scientific literacy, may approach genomics with varying degrees of understanding and with issues of concern that may overlap or may be significantly different (Aro et al., 1997; Henneman, Timmermands, & Wal, 2006).

The Human Genetics Commission (2000) found corresponding results in a public attitudes survey in the UK, stating that young people (< 25 years) possessed a more risk-taking attitude and better knowledge of biotechnology than older people did. While some of the risks and benefits of modern biotechnology are well enough understood to support the conclusion that it should, or should not be permitted at this time, there is a fragile balance between competing social and economic rights and interests (National Bioethics Advisory Commission, 1997).

Scientific interest

When students show an (scientific) interest in biotechnology and/or science chances are this will affect the overall attitude. Underlying this relationship may be higher levels of background knowledge, obtained in higher levels of education. Students who hold interest in (learning) science and technology in general are more likely to have intentions to engage in future learning behaviours (Norwich & Duncan, 1990). General scientific interest may therefore also be an important indicator of students' attitudes.

1.5. Research questions

The concept of attitude includes levels of knowledge as well as cognitive and affective evaluations and behavioural intentions, leading to certain attitudes. In the present study, we first examine to what extent background factors show a relationship with the four different attitudes (not sure, confident supporter, concerned sceptic, and not for me), and secondly examine correlations between different value factors and the four different attitudes towards biotechnology.

The following research question can be formulated:

What are the relationships between background factors and value factors on the one hand and attitudes towards biotechnology on the other hand?

2. Method

2.1. Participants

Based on a list of all Dutch schools in four large cities in the western part of the Netherlands, teachers were invited to participate with their students. A total of 47 schools were approached, of which thirteen consented to participate with one or more of their classes of sixteen-year-old students. A sample of 634 pupils from thirteen different schools in four large cities in the western part of the Netherlands completed a questionnaire on attitudes towards biotechnology, background, and value factors. In the Netherlands, the secondary education system for pupils aged between twelve and eighteen years is divided into three main levels: at lowest educational level; secondary vocational education (VMBO, 12-16 years), at medium educational level; general secondary education (HAVO, 12-17 years), and highest level; pre-university secondary education (VWO, 12-18 years).

Students were excluded from subsequent analysis if they completed less than 33.3% of the questionnaire or showed a suspicious answer-pattern, e.g., all questions were responded to in identical fashion, or included contradictions. This resulted in a dataset of 574 respondents. The students stemmed from these three different levels: low educational level, 25.6%; medium level, 25.6%; and high level, 48.8%. The sample consists of 262 males (45.6 %) and 312 females (54.4%), and the average age was 15.8 (SD = 0.66).

In the period from February through April 2004, teachers administered an on-line version of the questionnaire in a regular classroom.

2.2. Measures

In previous work, the development of the questionnaire on the underlying structure of attitude was reported (Klop & Severiens, 2007). Based on principal component analyses, several distinct and independent cognitive, affective, and behavioural factors were found, as described in Table 1.

Table 1. Attitude factors with scale name, description, typical items, reliability and descriptive values, based on principal component analyses

Attitude components	Attitude factors	Description	Typical item	Cronbach's alpha (No. of items)	Mean (SD)
Cognitive component	Biology and genetics*	Knowledge of biology and genetics	DNA contains the information for all you hereditary factors.	0.63 (n = 9)	7.10 (1.8)
	Biotech*	Knowledge of biotech applications	Normal tomatoes have, in contrast to GM tomatoes, no genes.	0.71 (n = 17)	13.80 (1.8)
	Beliefs	Evaluative knowledge of biotech / beliefs about biotech	I think genomics can solve food problems in the third world	0.70 (n = 5)	3.09 (0.64)
Affective component	Basic emotion	Basic emotional reactions	Genetic modification (GM) is bad.	0.78 (n = 13)	3.00 (0.58)
	Unavoidable	Feelings of biotech being unavoidable	Biotechnology is absolutely necessary.	0.76 (n = 9)	3.12 (0.62)
	Worries	Worries about biotech	How many worries do you have about genetic research?	0.79 (n = 5)	2.97 (0.79)
Behavioural component	Own intentions	Consuming intentions; own interest	I would eat GM food if it was cheaper than normal food.	0.78 (n = 5)	3.09 (0.82)
	Medical intentions	Medical intentions	Would you take a genetic test during your pregnancy?	0.74 (n = 4)	3.10 (0.83)
	Critical intentions	Consuming intentions; critical conditions	I would buy GM food if it were grown more environment-friendly than normal food.	0.74 (n = 3)	3.60 (0.90)

* bivariate data

Given the objective of the present study, we also constructed scales measuring the underlying values (ethical considerations, interest, benefit and risk perceptions). To this end, principal component analyses (PCA) and internal consistency was tested using Cronbach's alpha (α).

Ethical considerations

A PCA with varimax rotation was conducted on the responses to 48 items (on a five-point-Likert scale) stating the basic ethical questions about modern biotechnology applications. A solution with three factors turned out to be interpretable. The three factors explained 44.01% of the variance.

The first factor indicated ethical considerations involving medical applications or procedures, in the field of modern biotechnology, such as genetic research and gene technology. The measure was highly reliable, α = 0.90 (number of items = 15, see Table 2).

The second factor covered ethical considerations concerning the use of modern biotechnology for quality enhancement with a clear (qualitative) purpose, such as the use of genetic modification on crops for better resistance against diseases ($n = 14$, α = 0.90, see Table 2).

The third factor pointed towards the use of modern biotechnology for enhancement for 'handy' or funny but not 'life-saving' goals (more 'commercial use'), for example changing of genetic features such as eye-colour, or genetically modifying fish, making them glow in the dark ($n = 16$, α = 0.88, see Table 2).

Scientific interest

The questionnaire included 11 items that aimed to measure the students intrinsic interest (the sense that science is interesting of one's own accord) as well as their extrinsic interest (mainly interested in the subject for the outcome qualification) in biotechnology and science overall. Although PCA showed that the best solution is a two-factor solution with

Table 2. Distinct explanatory variables with factor name, description, typical items, reliability and number of items and descriptive values, based on principal component analyses

Explanatory variable	**Factors**	**Description**	**Typical item**	**Cronbach's alpha (No. of items)**
Ethical considerations	Medical applications	Medical use of modern biotechnology	Do you agree with the use of modern biotechnology for improving defective genes?	0.90 (n = 15)
	Qualitative use	The use of biotech to improve or change quality of organisms	To what extent do you agree with changing genes of tomatoes so that they have a longer storage life?	0.90 (n = 14)
	'Unnecessary' application	The use of biotech to improve or change features with no "real need"	Would you agree with changing of genetic features such as eye-colour?	0.88 (n = 16)
Interest	Interest	Interest in science	I find science interesting.	0.73 (n = 5)
Benefit	Benefit	Benefits of modern biotechnology	The benefits of science are larger than the possibly negative effects.	0.78 (n = 13)

11 items (explained variance is 38.9%), reliability analysis could only be confirmed for the intrinsic interest ($n = 5$, $\alpha = 0.73$, see Table 2).

Benefit & Risk

Twenty-three statements intended to cover items concerning benefits and risks-considerations of modern biotechnology, as broadly and as relevantly possible. Again a principal component analysis was performed. It showed a two-factor solution, for both risk factors and benefit-factors, but no acceptable Cronbach's alpha for risk could be obtained (highest reliability was an alpha of 0.60). It was decided to just include the benefit-factor as a scale in subsequent analyses (n = 13, alpha = 0.82, see Table 2).

2.3. Variables

The *dependent* variable in our study, attitudes towards biotechnology, is divided into four groups based on cluster analyses (for details see Klop & Severiens, 2007). These four groups are the 'confident supporter' group, the 'not sure' group, the 'concerned sceptic' group and the 'not for me' group. The independent variables are described below.

Independent background variables:

- Gender: male or female,
- Religion: a distinction is made between two main religious groups (Christian and Islamic), no religion, and a group comprising 'other religions'.
- Ethnic background: majority and minority background. Respondents stem from a large variety of non-native backgrounds (total of 42 different countries), making it impossible to perform reliable statistical tests on all minority backgrounds. Therefore, we divided the respondents into majority and minority backgrounds, following the standard definition of a person with a minority background (Netherlands Statistics CBS): 'A Person who is a Dutch resident and of whom at least one parent is born abroad.'
- SES: the average of mother and/ or father's educational level was used as a measure of respondent social economic status (SES).
- Experience with biotechnology: having a genetic disorder yourself or someone within the family or relatives, or knowing someone who works in the related work field of modern biotechnology.
- Educational level and achievement:
  - Educational level; low, middle or high educational level.
  - Grade: low, middle, or high average grade. Measured by several general and science examination subjects[1].

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[1] Dutch, English, biology, mathematics, and science.

  - Biology / or science as final-examination subject chosen by students.
- Value factors; see previous section for descriptions.

2.4. Analyses

The statistical analyses regarding the relationships between the independent variables and the attitude towards biotechnology (as indicated by membership of one of the four attitude-groups) were done stepwise. The first step in the analysis was to determine whether there is an association between the (independent) background factors and the four attitude-groups. In the second step, all value factors (ethical considerations, benefit perception, interest) were included in the analyses as well. These objectives were accomplished by means of multinomial logistic regression (MLR). This type of regression analysis enables the prediction of discrete dependent variables (in our case attitude as indicated by group membership) with either nominal or ordinal independent variables (Hosmer & Lemeshow, 1989).

Data was analysed by means of the Statistical Package for Social Sciences software, version 12.0.1 (SPSS).

Some of the background and value factors may be inter-related, for example, science achievement and gender, or scientific interest and educational level. In addition, ethnic background and religious background, and religious background and ethical considerations are all explanatory factors that may be inter-related. In multivariate analyses of variance, this may cause multi-co linearity and result in odd relationships, or disguise relationships that actually do exist. We have dealt with this possible problem by performing the analyses in two steps as described above, and we conducted post-hoc analyses to further explore the relationships and look for the best fitting models.

3. Results

3.1. Multivariate analyses[2]

In logistic regression, parameters are typically interpreted using odds ratios [exp. (B)]. An odds ratio describes 'the odds of a categorical outcome at one level of a categorical predictor relative to the odds of the outcome at a comparison level (i.e., the reference category)' (Kilpatrick et al., 2000, p.22). Odds ratios above 1.0 indicate an increased likelihood where as ratios between 0 and 1 indicate a decreased likelihood. The 'not sure' cluster (most students) was set as reference category since this is the least outspoken and largest group. The results are reported in Table 3 and 4.

[2] For basic statistics; see appendix I and II.

In the first regression analysis with background factors, only three background variables were significantly related to attitudes. These were gender, level of education and the choice of biology as examination subject.

Male students were well over three times more likely to be confident supporters then not sure's (see the odds ratio of 3.18 in Table 3).

Students with a higher educational level were 1.5 times more likely to be confident supporters and 0.2 more likely to reject biotechnology compared to the 'not for me' group (the odds ratio being smaller than 1 implies a decreased likelihood).

The same results were found for 'bio in exam'. Students, who chose biology as an exam-subject were 2.04 times more likely to be a confident supporter and 0.24 times more likely to be in the 'not for me' cluster, compared to the reference group.

No significant effect could be established for the sceptic group. In other words, similar percentages of boys and girls, educational levels, and those choosing biology as an examination subject, were found within the sceptical cluster.

3.1.1. Post-hoc analyses

Ethnic background, nor religion nor SES showed a significant relationship with attitudes in the multivariate analysis. Because an inter-relationship between these variables can be expected based on former research, post-hoc analyses are performed. With these

Table 3. Logistic regression analysis for background factors by Clusters (step 1)

	Likelihood ratio tests				*P-value*			*Odds ratio*		
	chi-square	df	sig.		cluster1	cluster3	cluster4	cluster1	cluster 3	cluster 4
Intercept	0.00	0	.	.	.001	.841	.000			
Gender	34.36	3	.000*	male	.000*	.141	.766	**3.18**	0.68	0.92
				female	.	.	.	.	.	.
Personal experience	3.49	3	.323	exp	.463	.296	.371	0.84	1.30	0.75
				no exp	.	.	.	.	.	.
Religion	12.88	9	.168	chris.	.149	.031	.956	0.68	1.81	1.02
				islam	.734	.057	.130	1.21	2.92	2.32
				other	.834	.172	.899	0.92	1.73	1.06
				no relig.	.	.	.	.	.	.
Ethnic background	2.41	3	.492	native	.416	.320	.862	0.80	1.36	0.94
				non native	.	.	.	.	.	.
SES	1.65	3	.647	ses	.890	.838	.232	1.05	0.94	0.69
Educ. level	91.32	3	.000*	educ level	.017**	.176	.000*	**1.53**	0.80	**0.20**
Grade	2.57	3	.464	grade	.373	.648	.307	1.34	0.85	0.64
Bio as exam.-subject	40.86	3	.000*	yes	.004**	.119	.000*	**2.04**	0.67	**0.24**
				no	.	.	.	.	.	.

The reference category is: cluster2; not sure.
Model fit criteria: -2 Log Likelihood=1116.00, $\chi2$=209.84, df=30, p<.001; Nagelkerke R Square= .330
*$p < .001$, **$p<.05$.

analyses, we examined whether co-linearity between ethnic background and religion (students with a native Dutch background more often have a Christian religion and minority students an Islamic or other religious background) disguised the relationships in multivariate analyses.

This was not the case. In additional analyses, leaving out either religion or ethnic background still showed no significant relation with the attitude-clusters (data is not shown).

A second possible co-linearity could exist between religion or ethnic background on the one hand and educational level on the other hand. Students from non-native backgrounds, as well students from Islamic backgrounds, are also more often from lower educational levels (appendix I). An additional multivariate analysis, excluding educational level, indeed showed significant relationships with attitude. In this case, the 'not for me' group consists not only out of students in the lower levels of education; also students with a minority background were over-represented (data is not shown).

In the second step, the value factors as well as the significant background factors of step 1 (i.e. gender and the school factors) were included in logistic regression (Table 4). The results showed that of all background factors, educational level and biology in exam remained significantly associated with attitude. Furthermore, all value factors except for interest were significantly related to attitudes towards biotechnology.

Gender

Apparently, the differences between boys and girls have 'disappeared'. A possible cause is that gender difference can be explained by the value factors.

In post-hoc analyses, this explanation was confirmed for gender differences with the ethical considerations, but not for differences in interest. Boys and girls differed considerably in their ethical point of views, thereby over-ruling the main effect of gender itself. Girls were more often critical in their ethical considerations compared to boys (medical applications, $t = 2.54$, $p= .10$; qualitative use $t = 5.87$, $p = .00$; unnecessary application, $t = 8.16$, $p = .00$) (data not shown).

3.2. Value factors

Ethical considerations

Students giving positive answers to the ethical questions regarding medical applications were less likely to be concerned sceptics (0.36), and less likely to reject biotechnology (0.30) (see Table 4). Students with positive answers regarding the qualitative utilisation of biotechnology were more than eight times likely to be 'confident supporters' and respectively 0.40 and 0.18 more likely to be 'concerned sceptics' or 'not for me's'. Remarkably, students with no ethical objections to the somewhat "unnecessary use of biotechnology", were 2.63 times more likely to be in the 'not for me' group (see Table 4). In other words, whereas the 'not for me' group negatively answered all other ethical issues, they seemed to have fewer problems with some of the probable commercial applications of modern biotechnology then did the other groups. This unexpected result will be discussed in the conclusions.

Benefits

Students expecting high benefits from biotechnology were 3.18 time more likely to be confident supporters, they were 0.22 times more likely to be sceptics, and 0.24 times more likely to be in the 'not for me' group, compared to the 'not sure' reference group of students.

In sum, compared to the baseline 'not sure' group, confident supporters more often stemmed from high educational levels, held positive ethical views and expected benefits from the development in modern biotechnology.

The concerned sceptics were from similar educational levels and also choose biology as an examination subject. However, they did hold different ethical considerations compared to the 'not sure' group. They were more negative about medical applications and more

Table 4. Logistic regression analysis for significant background factors and explanatory variables by Cluster (step 2)

	Likelihood ratio tests					**P-value**			**Odds-ratio**		
Factors		chi-Square	df	sig.	scales	cluster1: confident	cluster3: sceptic	cluster4: not for me	cluster1: confident	cluster3: sceptic	cluster4: not for me
	Intercept	0.00	0	.		.000	.000	.000			
Background factors	Gender	2.17	3	.538	male	.150	.879	.969	1.58	0.95	1.01
					female	.	.	.	.	.	.
	Educational level (school factor)	59.71	3	.000*	educ. level	.008**	.292	.000*	**1.75**	0.83	**0.25**
	Bio in exam (school factor)	15.17	3	.002**	yes	.082	.513	.002**	1.79	0.82	**0.30**
					no	.	.	.	.	.	.
Ethical considerations	Medics	15.81	3	.001*	medics	.316	.003**	.001*	1.52	**0.36**	**0.30**
	Qualitat	47.12	3	.000*	qualitat.	.000*	.013**	.000*	**8.26**	**0.40**	**0.18**
	Unness	27.88	3	.000*	unness.	.100	.023**	.003**	1.60	**0.52**	**2.63**
Interest	Interest	5.42	3	.144	interest	.049	.566	.315	1.46	0.90	0.81
Perception of benefit	Benefit	23.836	3	.000*	benefit	.021**	.001*	.002**	**3.18**	**0.22**	**0.24**

The reference category is: cluster2; not sure.

Model fit criteria: -2 Log Likelihood=878.21, χ2=565.52, df=24, p<.001; Nagelkerke R Square= .693

* *p* < .001; **p<.05

negative about biotechnology in a qualitative sense. Last, the concerned sceptics saw the least benefits of modern biotechnology of all clusters. Of all attitude-clusters under consideration, the students that are negative about biotech, the 'not for me' group, differed the most in comparison to the 'not sure' group. The negative group stemmed from lower educational levels, and did not often include biology in their exam. Furthermore, they were more negative regarding the ethical considerations, and did not see many benefits.

4. Conclusions

A well thought about opinion on modern biotechnology has become a necessary asset given the recent rapid scientific developments in this field with its potentially major societal impact (Waarlo et al., 2002). It seems important to advocate scientific literacy in this particular field. In a former study, it was found that almost half of the Dutch secondary students (coming from all different educational levels) were not sure what to think of biotechnology (Klop & Severiens, 2007). This finding shows the general importance of encouraging students to further develop their attitudes. Moreover, it shows the importance of exploring students' attitudes in further detail. What kinds of students are not sure about their opinion? In addition, and perhaps more informative given the ultimate goal of stimulating scientific literacy in science education, how can we describe the remaining students who do hold an explicit opinion (negative or positive)? The present study will answer these questions by analysing factors that are important in explaining students' attitudes towards biotechnology.

In this final section, the results are summarised and discussed, and the major implications for education and for further research will be presented.

For over two decades, there has been a tradition of research on gender issues in the science classroom. Several studies have examined gender differences in students' general attitudes toward science and technology (Hill et al., 1998; Jones et al., 2000; Kotte, 1992; OECD, 2007) or in cognitive factors or differences in interest (Neathery, 1997; Schibeci & Riley, 1986). They have consistently found that boys have more favourable attitudes toward science then do girls. Most studies on gender differences have focused on differences in cognitive factors or differences in interest. The present study confirms former results on gender differences in respect to general attitudes towards modern biotechnology: boys seemed more often confident supporters of biotechnology, whereas girls were more often concerned sceptics or not sure what to think of it. However, when value factors were taken into account, gender differences disappeared. The differences between boys and girl could not be explained by the difference in interest in science, but by a different way of considering ethical issues in biotechnology. On all ethical considerations, girls seemed to be much more reserved and concerned (appendix I). An explanation for this matter might be girls' concerns with future issues (i.e. pregnancy issues) are different from those of boys (Huijer & Horstman, 2004).

The ethical points of view of students, as well as their perception of benefits were strongly related to their overall attitudes towards modern biotechnology. It seemed that when students were more restricted in allowing biotechnology applications they had a more overall critical attitude concerning modern biotechnology, especially when it comes to the medical and qualitative fields of biotechnology. The more critical groups also seemed to expect less benefits of modern biotechnology compared to students within the neutral or positive groups.

When it comes to the uses of biotechnology for 'unnecessary purposes' (e.g., changing of genetic features such as eye-colour), the negative students in the 'not for me' group, were neutral, despite their relatively negative answers to the other ethical issues. How can this seemingly contradictory finding be explained? We know that the 'not for me' group consists of students with relatively little knowledge on the subject, and that they are over-represented in the lower levels of education (appendix I). Perhaps their lack of knowledge does not keep them from an initial positive feeling towards some of the seemingly unnecessary but in terms of gadget value, attractive possibilities of biotechnology, like "glow in the dark- fishes" (see section 2.2.1). A qualitative research study could investigate this and possible other explanations in further detail.

Level of education and choosing biology as final-examination subject showed a strong and significant relationship with the different attitudes. Posthoc analyses showed that this relationship overrules the relation with religious and ethnic background (and SES). This result is in accordance with recent research, where school levels have been shown to be related to both civic scientific literacy and to attitudes towards science and technology in general (Gaskell et al., 2003; Pardo et al., 2002; Zacharia & Barton, 2004). Taking all results into account, it can be concluded that the higher the level of education and the more often they choose biology as examination subject, the more positive the attitude of students. Conversely, students in the lower levels are more negative about biotechnology. These results confirm former research on the relationship between knowledge and attitude towards biotechnology (Pardo et al., 2002).

4.1. Implications for science teaching and communication

The findings of this study highlight issues that may have to be considered by curriculum planners and science teachers who wish to incorporate scientific literacy into science curricula. When educating students about modern biotechnology and its implications, one has to keep in mind that background factors play an important role on several attitude factors, cognitive as well as affective elements. If the goal is to help students to develop their attitudes, this finding shows the importance of incorporating values into educational programmes as well.

In other words, science education should not only focus on what or how this subject is taught, but also to whom. Paying attention to ethical views, and inviting students to think about benefits and risks more closely might help different groups of students to create a more balanced attitude towards biotechnology. Especially for the groups that are at higher risks of lagging behind on the development of scientific literacy. School science, and to greater extent scientific literacy, should be aimed at all students, so that their needs can be met to become informed citizens.

These findings should be taken into account in the development of educational programmes for secondary school students on informed decision-making towards modern biotechnology.

4.2. Future research

In the present study a set of questions was developed to measure risks and benefits of biotechnology. Based on these questions, it was not possible to establish a reliable scale measuring the perception of risk. The reason for this might be that the future prospect of modern biotechnology is very unsure. Pardo et al (2002) experienced a similar problem; their structural model failed to predict the perception of risk. It remains unclear however, why on the other hand the perception of benefits can be measured reliably. It suggests that benefits of biotechnology refer to one underlying dimension (you either see benefits, or you do not), whereas risks of biotechnology refer to a number of underlying dimensions resulting in an unreliable scale. Future research should focus more on the possible underlying dimensions of this matter. A more qualitative design is suggested to uncover these dimensions.

The present study leaves at least two questions unanswered. The first question concerns the effect of religion and ethnic background, in relation to the effect of educational level. As explained in the results, level of education seems to be a stronger predictor than religious and ethnic background. At the same, we have to stress that numbers of students participating in our study from non-native backgrounds and from the different religious groups are relatively small. Moreover, it should also be borne in mind that these non-native and religious students constitute a very heterogeneous group with a diverse range of skills, backgrounds, and motivations. We therefore have to be careful with our conclusion that educational level is more important than ethnic or religious background. Our suggestion for future research would be to conduct a qualitative study, including students from each religious and ethnic group, within each educational level. Such a design could provide a more detailed answer to our research question about the effects of religion, ethnic background, and educational level on attitude towards modern biotechnology.

Our study indicates which background factors and underlying views seem important determinants of attitude. It would be interesting to examine educational programmes that actually attempt to incorporate these so-called attitudinal indicators. Such a program would pay attention to each component of attitude (cognition and affection) and to variables such as ethical points of view, and perception of benefit and risk. The second question for a future research study would be to what extent such educational programmes are more effective compared to more traditional science education. In other words, would such an educational programme increase the number of "students with a view"?

Appendix I. Nominal background factors of the four attitude clusters in percentages

Cluster identity		cluster 1: confident supporter (n = 130)	cluster 2: not sure (n = 239)	cluster 3: concerned sceptic (n = 105)	cluster 4: not for me (n = 100)	total no. (%)
Gender [a]	male	31.2	37.0	13.7	17.2	262 (45.6%)
	female	14.7	45.5	22.1	17.6	312 (54.4%)
Personal experience [b]	experience	23.5	44.4	21.4	10.7	196 (34.1%)
	no experience	22.2	40.2	16.7	20.9	378 (65.9%)
Religion [c]	christian	18.3	41.9	22.5	17.3	191 (33.3%)
	islamic	16.3	22.4	22.5	33.8	49 (8.5%)
	other religion	20.5	38.4	20.5	20.5	73 (12.7%)
	no religion	27.6	46.0	14.6	11.9	261 (45.5%)
Ethnic background [d]	native	23.0	44.0	19.0	14.0	400 (69.7%)
	non-native	21.8	36.2	16.7	25.3	174 (30.3%)
Biology as exam.-subject [e]	yes	26.5	43.0	17.8	12.6	309 (53.8%)
	no	18.1	40.0	18.9	23.0	265 (46.2%)

a *Chi-Square = 26.80. df = 3. p = .000*
b *Chi-Square = 9.915. df = 3. p = .019*
c *Chi-Square = 38.36. df = 9. p = .000*
d *Chi-Square = 11.07. df = 3. p = .011*
e *Chi-Square = 13.73. df = 3. p = .003*

Appendix II. Ordinal variables; comparison of mean (*SD*), F-value, df and p-value among the four groups

	Factors	cluster 1: confident supporter	cluster 2: not sure	cluster 3: concerned sceptic	cluster 4: not for me	F	df	p
School factors*	edu. level	2.58 (.65)	2.38 (.76)	2.21 (.86)	1.46 (.70)	48.16	3	.000
	grade	2.19 (.37)	2.13 (.35)	2.09 (.32)	2.04 (.31)	3.55	3	.014
SES*		1.85 (.36)	1.80 (.40)	1.77 (.42)	1.60 (.49)	7.64	3	.000
Ethical considerations	medics	4.30 (.46)	3.82 (.46)	3.26 (.46)	3.06 (.63)	139.84	3	.000
	quality	4.03 (.47)	3.37(.43)	2.86 (.53)	2.78 (.65)	152.10	3	.000
	unness	3.09 (.67)	2.49 (.59)	2.14 (.70)	2.59 (.67)	47.5	3	.000
Interest	interest	3.33 (.81)	2.86 (.82)	2.88 (.87)	2.57 (.86)	19.57	3	.000
Benefit perception	benefit	4.01 (.38)	3.57 (.39)	3.12 (.45)	2.98 (.53)	138.83	3	.000

* Background factors

Chapter 4

Effects of a science education module on attitudes towards modern biotechnology of secondary school students: A quasi-experimental design study

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Abstract

This article evaluates the impact of a four-lesson science module on the attitudes of secondary school students. This science module (on cancer and modern biotechnology) utilises several design principles related to a social constructivist perspective on learning. The expectation was that the module would help students become more scientifically literate in this particular field. The concept of attitude was adopted as a measure of the level of science literacy. In a quasi-experimental design (experimental, control groups and pre- and post-tests) secondary school students' attitudes (n = 365) towards modern biotechnology were measured by a questionnaire. Data were analysed using chi-square tests. Significant differences were obtained between the control and experimental conditions. Results showed that the science module had a significant effect on attitudes, although predominantly towards a more supportive and not towards a more critical stance. It is discussed that offering a science module of this kind can indeed encourage students to become more scientifically literate, although promoting a more critical attitude towards modern biotechnology should receive more attention.

1. Introduction

~"Education is not to reform students or amuse them or to make them expert technicians. It is to unsettle their minds, widen their horizons, inflame their intellects, and teach them to think straight, if possible."~
Robert M. Hutchins

As a scientific discipline, modern biotechnology goes hand-in-hand with cultural, social, and public policy controversies. The development of theories and techniques enables scientists to alter the genetic code of practically all living organisms. Genes and gene combinations that control a wide variety of traits are described. Several genetic anomalies causing disorders such as cystic fibrosis, Huntington's disease and several types of cancer have been identified. Biotechnological applications of all kinds are in the making and already evident in a growing range of genetically modified foods in supermarkets. Discoveries from the field of biology can fundamentally change society and human self-perception in the 21st century.

This scientific revolution requires a scientifically literate population, meaning that people should be able to make informed and balanced decisions about scientific issues concerning their careers, their daily lives, and society as a whole (National Academy of Sciences, 1996).

Promoting scientific literacy is widely recognised as a major goal of school science education (Millar, 2006). However, there is still considerable uncertainty about the meaning of 'scientific literacy' and the implications for the science curriculum (DeBoer, 2000; Hodson, 2002; Jenkins, 1990; Kolstø, 2001; Laugksch, 2000). Consequently, there are varying interpretations of how and what kind of abilities should be incorporated into school science curricula in order to help students become scientifically literate. The question is what is important for students to know, value, and be able to do in situations involving science and technology. Current thinking about the desired outcomes of science education emphasises scientific knowledge and an appreciation of science's contribution to society. These outcomes require an understanding of important concepts and explanations of science, and the strength and limitations of science in the world (OECD, 2006). Conceptualisations of scientific literacy range from understanding lay articles in newspapers and popular magazines (Millar & Osborne, 1998), an appreciation of the nature, aims and general limitations of science (Jenkins, 1992), to the abilities of a semi-professional scientist (Hazen & Trefil, 1991; Thomas & Durant, 1987). This paper follows Millar's (2006) starting point in that science education should aspire to include scientific literate competences that students need to be able to live and participate with reasonable comfort, confidence, and responsibility in a society that is deeply influenced and shaped by the applications, ideas and values of science. These competencies require students to demonstrate, on the one hand, cognitive abilities and on the other, values and motivations as they meet and respond to socio-scientific issues (Bybee, 1997; Holbrook & Rannikmae, 2007; Kolstø, 2001; Shamos, 1995; Zeidler et al., 2002).

1.1. Scientific literacy and attitudes towards modern biotechnology

The purpose of science education should be helping students to participate in discussions about science, to be sceptical and questioning of claims made by others about scientific matters and to make informed decisions about the environment, their own health and well-being (in accordance with Driver et al., 2000; Goodrum et al., 2001; Kolstø, 2001; National Science Council, 1996). According to Osborne (2000), this broad focus will help students to tackle everyday decisions with a science or technology dimension, such as whether to buy a tube of genetically modified tomato paste.

In order to examine the effects of science education on scientific literacy, it is important to construct a measure that will be sufficiently sensitive to capture changes in the structure of its composition (Millar, 2006). The tripartite theory of attitude provides a helpful framework in the construction of this measure of changes in scientific literacy. This theory defines an attitude as a combination of cognitive, affective, and behavioural components (Breckler, 1984; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960). Attitudes towards modern biotechnology are the product of knowing and thinking about biotechnology (the cognitive component), feelings and emotions about biotech issues (the affective component), and behavioural intentions towards biotechnology and its applications (the behavioural component). It is this particular combination of thinking, feeling and acting that relates to the concept of scientific literacy (Chin, 2005). Our line of argument is that when students have a solid knowledge base on basic biological and genetic concepts, when they display an affective reaction of concern or comfort towards biotech issues (as opposed to an indifferent reaction) and they have comprehensible ideas on how to behave or make decisions when confronted with modern biotechnology, i.e. when students have profound attitudes, they can be considered scientifically literate ('genomic literacy').

1.2. Previous study on attitudes towards modern biotechnology

According to this line of argument, scientific literacy requires (1) a solid knowledge base of basic scientific constructs (cognitive component), (2) a clear stand on one's own feelings and emotions with regard to important (social and ethical) issues (affective component) and (3) the ability to make informed decisions about the environment, one's own health and well-being (behavioural component). The definition of scientific literacy proposed here provides for a continuum from less developed to more developed – that is, individuals are deemed to be more or less scientifically literate; they are not regarded as either scientifically literate or illiterate (Bybee, 1997; OECD, 2006). The results of the previous study on attitudes (Klop & Severiens, 2007) showed that attitudes towards biotechnology are a multi-component concept, consisting of different patterns of cognitive, affective and behavioural features (see Table 1).

The four emerging patterns were labelled 'confident supporter' (22% of the students), 'concerned sceptic' (18%), 'not for me' (17%) and 'not sure' (42%) (see Figure 2 for a graphic representation).

The 'confident supporters' were a positive, pro-biotechnology, and well-informed group of students who seemed to welcome biotechnology in their daily lives. This group can be labelled as more scientifically literate, for they seemed to be well aware of scientific

Table 1. Attitude factors with scale name, description, typical items, reliability and descriptive values, based on principal component analyses

Attitude components	Attitude factors	Description	Typical item	Cronbach's alpha (No. of items)	Mean (SD)
Cognitive component	Biology and genetics*	Knowledge of biology and genetics	DNA contains the information for all you hereditary factors.	0.63 (n = 9)	7.10 (1.8)
	Biotech*	Knowledge of biotech applications	Normal tomatoes have, in contrast to GM tomatoes, no genes.	0.71 (n = 17)	13.80 (1.8)
	Beliefs	Evaluative knowledge of biotech / beliefs about biotech	I think genomics can solve food problems in the third world	0.70 (n = 5)	3.09 (0.64)
Affective component	Basic emotion	Basic emotional reactions	Genetic modification (GM) is bad.	0.78 (n = 13)	3.00 (0.58)
	Unavoidable	Feelings of biotech being unavoidable	Biotechnology is absolutely necessary.	0.76 (n = 9)	3.12 (0.62)
	Worries	Worries about biotech	How many worries do you have about genetic research?	0.79 (n = 5)	2.97 (0.79)
Behavioural component	Own intentions	Consuming intentions; own interest	I would eat GM food if it was cheaper than normal food.	0.78 (n = 5)	3.09 (0.82)
	Medical intentions	Medical intentions	Would you take a genetic test during your pregnancy?	0.74 (n = 4)	3.10 (0.83)
	Critical intentions	Consuming intentions; critical conditions	I would buy GM food if it were grown more environment-friendly than normal food.	0.74 (n = 3)	3.60 (0.90)

* bivariate data

concepts and processes and were able to take a clear position regarding environmental, health and personal issues.

The 'concerned sceptics' were also a well-informed group of students and also labelled as more scientifically literate. Not only did they show a solid knowledge base on basic biological and genetic concepts, they demonstrated a sceptical, concerned and questioning stance towards claims made about modern biotechnology as well.

The smallest group, the 'not for me' students, was very negative about biotechnology. Their beliefs and affective reactions were very negative and unfortunately, they displayed poor knowledge and understanding of the subjects. The last cluster, the so-called 'not sure' group, formed the largest segment. Their views tended to be rather unclear; they were neither anti-biotechnology nor pro-biotechnology and their overall understanding of the subjects left something to be desired.

In other words, more than half of the 16-year old students is considered less or poorly scientifically literate. These students had a limited knowledge base of the key concepts and principles of modern biotechnology (especially the 'not for me' group) and unclear or poorly developed views or opinions on important social and ethical issues. They were not sure about their intentions towards possible biotechnological applications and were not sure what to expect of genomics in general. Even students with somewhat more knowledge on the subject (the 'not sure' group) seemed to have little awareness and showed little concern about the possible impact that modern biotechnology could have on society and thereby their own (future) lives. In other words, they did not use their 'scientific knowledge and ways of thinking for personal and social purposes'. In that sense, these students lack the ability needed in order to be considered effectively scientifically literate.

1.3. Features of a new science module

The question is how scientific literacy can be promoted in science classes; in what ways can science education encourage students to learn about (bio-) technological issues concerning society, their careers and their daily lives, so-called socio-scientific issues (Sadler, 2002; Zeidler & Keefer, 2003; Zeidler et al., 2002) and develop a critical opinion? In order to help young people engage in the social practice of scientists, learning contexts must be chosen so that students can make sense of it and give them a feeling of responsibility to participate critically. However, at the level of educational practice, inspiring examples are relatively sparse. Moreover, empirical research into the effectiveness of such educational practices appears to be lacking (Hodson, 2003).

Therefore, we decided to examine the effects of a new Dutch science module on genomics and cancer, on students' scientific literacy. We will first present the structure of the science module and then specify the underlying design principles.

The genomics research centre of excellence (CGC)[1] of the University Medical Centre of Utrecht developed a new science module for the upper levels of secondary education. The socio-scientific topic of the science module is genomics and cancer research; titled 'Read the language of the tumour' ('Lees de taal van de tumor'). A so-called travelling DNA lab gives students the opportunity to encounter new and sophisticated research techniques. By giving a realistic picture of genomic-research, the module aims at students' acquisition of knowledge on the subject of genomics. Moreover, it is intended to stimulate the opinion forming and critical reflection of students towards genomics and the implications of the applications on society (Waarlo, 2005; 2007).

The science module consists in four lessons; an introductory lesson, two practical/ hands-on lessons (in succession) and a reflection lesson (see Figure 1).

Lesson 1 Introduction	Lesson 2 "The genomics lab"	Lesson 3 "The genomics lab"	Lesson 4 Reflection

Figure 1. Design of the experimental science module

During the introductory and reflection lesson, instruction and guidance was given by the teacher him-/herself. The practical lessons, a 'DNA-lab setting' at school, were supervised by two trained students of the university. Teachers that signed up for the science module received a detailed teacher manual and workbooks for their students.

The introductory lesson included a brainstorm-session and an opportunity to raise questions on the topic of cancer and cancer research. The lesson was designed to connect with students' prior knowledge of the subject matter, since students were already presumed to have at least some background knowledge and ideas about social or ethical matters relating to cancer and/or biotechnological research.

After activating prior knowledge and clarifying ideas or difficulties, students were invited to discuss their questions about and experiences with cancer and cancer research in small groups first and then in the whole class.

During the second and third lessons, students had to perform an assignment in a genomics lab setting. They worked in small groups (two or three students), under the supervision of two university students. In this genomics laboratory setting, using a hands-on approach, the students were invited to use actual genomic techniques. This gave them an opportunity to visualise abstract biological concepts: observing (and in some cases, touching) preserved cancer tumours, extracting DNA from a thymus gland (calf), and demonstrating pathogenic defects in genes by carrying out polymerase chain

[1] The Cancer Genomics Centre (CGC) is a strategic collaboration of research groups from the Netherlands Cancer Institute, the Erasmus Medical Center, the Hubrecht Laboratory, and the University Medical Centre Utrecht.

reaction (PCR) and gel-electrophoresis. Combined with exploration and discussion of the relevance and complications of cancer research for patients, their relatives and society, genomics was placed in a social and moral context.

A week after the lab lessons, during the fourth lesson, the students were asked to reflect on their hands-on experiences. They had to draw conclusions from the experiments and to complete a fictional counsel form that laboratory researchers use to write down their findings and conclusions. The students were given the role of a researcher by having to give treatment recommendations to a doctor. They had to read non-specialist articles on socio-scientific issues (breast cancer) in class and to reflect on their own questions formulated at the introductory lesson. There was room for ethical discussions, so the experiments could be placed in a broader, societal context and students could reflect on experiences, feelings, and thoughts.

The science module utilised several design principles, which can be derived from a social constructivist perspective on learning. The metaphor of participation is often used to characterise this concept of 'learning' (Salomon & Perkins, 1998; Sfard, 1998). In essence, social constructivist educational theories interpret learning as increasingly competent participation in the discourse, norms and practices associated with particular communities of practice (Lave & Wenger, 1991; Wenger, 1998). Becoming a more central participant in society is not just a matter of acquiring knowledge and skills. It also implies becoming a member of a community of practice. For this to happen, learning contexts must be chosen such that students can make sense of the subject matter and hence give them a feeling of responsibility to participate critically in the practice in question.

Over the last decade, elements of social constructivist conceptions of learning have been used in science education (Frijters et al., 2008; Ogborn, 1997). In particular, the interest in how students learn to think critically about social issues is increasing (e.g., Driver et al., 2000; Kolstø, 2001; Sadler & Zeidler, 2005). Improving science education is interpreted as helping young people to engage with the social practice of scientists. Against the background of this social constructivist perspective on learning, we can describe the module "Read the language of the tumour" in terms of five design principles:

1 Stimulates active learning
2 Stimulates inquiry-based learning
3 Uses authentic tasks
4 Stimulates reflection
5 Uses socio-scientific issues

1 Stimulating active learning.

Generally speaking, active learning is a process where students engage in higher-order thinking tasks, such as analysis, synthesis and evaluation. From a social constructivist point of view, the active role of learners is explicitly linked to the processes of making sense. Students are not seen as passive receivers of information but as active interpreters of social meanings. Ogborn (1997) advocated learning arrangements in science education in which the learner is actively involved in the integration of new experiences and information into what he or she already knows. In the module, the active contribution of students was facilitated in several ways. Throughout the module, students were encouraged to formulate and ask their own questions about cancer and cancer research. In the brainstorm session (first lesson), they had to write down their own opinions and questions, discuss them in a small group and afterwards within the context of a class discussion. Furthermore, active learning was stimulated by making use of authentic learning tasks (see item 4.).

2 Stimulating inquiry-based learning.
According to Wells (1999), a class should function as a community of inquiry in which each student makes her or his own contribution.

This social constructivist element is also present in science education research. A large number of studies have shown that inquiry-based science activities have positive effects on students' cognitive development, self-confidence, science achievement, attitude improvement towards both science and school and conceptual understanding of science as a whole, compared to a more conventional approach to science education (Butts, Koballa, & Elliott, 1997; Gibson & Chase, 2002; Jarrett, 1999; Zacharia, 2003). Rutherford (1993) stated that 'hands-on and learning by inquiry are powerful ideas, and we know that engaging students actively (…) pays off in better learning.' One of the building blocks of the module is the assumption that the actual performance of (genomics) techniques, combined with an exploration of the social and moral implications of cancer, can positively influence scientific literacy. The students were invited to learn through an inquiry-based and hands-on approach. Students learned about concepts of cancer, cancer research, and genomics by examining a real world, open-ended scenario and worked towards providing solutions that made sense to them.

3 Using authentic tasks.
Authentic tasks resemble tasks performed in a non-educational setting (real-life tasks or activities) and require students to apply a broad range of knowledge and skills (Newmann & Wehlage, 1993; Roth, 1999). The tasks refer to complex situations, contain open-ended, ill-defined problems and often require a multidisciplinary approach as well as collaborative work (ten Berge, Ramaekers, Brinkkemper, & Pilot, 2005). Authentic tasks are believed to help students to become aware of the relevance and meaningfulness of what they are learning because the tasks mirror real-life experiences and provoke active and constructive learning (Lowyck, 2005). Thus, besides developing knowledge, skills and attitudes,

it is assumed that authentic tasks increase motivation (Herrington & Oliver, 2000). This makes authentic tasks particularly suitable for helping young people to engage with the social practice of scientists and stimulate scientific literacy. According to Grabinger (1996), science and technology components should be looked upon from students' perspectives. In the module, authentic tasks were developed around the scientific concept of genomics using issues that are meaningful in students' lives (cf. Goodrum et al., 2001). The module was about cancer and cancer research, which provides a realistic and authentic context, as almost everyone has a relative who has dealt or is dealing with cancer.

4 Stimulating reflection.

From a social constructivist perspective, education should aim at teaching students to participate in society in a critical and aware manner. Performing authentic tasks in itself does not necessarily result in such an outcome. Issues to be dealt with should be made explicit, for example through dialogue in the classroom. Dialogue is generally considered a powerful instrument for reflection (Waarlo, 2005; Wells, 2000). Several researchers have noted the important role of reflection as a learning activity in developing scientific literacy (Sadler & Zeidler, 2004; Zeidler et al., 2005; Zeidler et al., 2002). By reflecting on thoughts, feelings and actions, students create a meaningful picture of their experience of the world, for which they will take responsibility. Empirical studies on effectiveness of science education state that science education should not only focus on knowledge and understanding but also reflect on the affective and ethical side of biotechnology (for example Chiappetta, Sethna, & Fillman, 1991; Lee et al., 2003; Wilkinson, 1999). In this science module, in the final lesson, the students reflected on the hands-on experience by writing down their findings and conclusions. Moreover, they read articles in class and reflected on their own questions formulated during the introductory lesson. Throughout the module, the students were encouraged to engage in (ethical) discussions with their peers in order to reflect on their own experiences, feelings, and thoughts.

5 Using socio-scientific subjects.

Finally, cancer and cancer research encompass socio-scientific issues. Issues, such as cloning, stem cell research, genetic testing, and genetically modified foods will play a significant role in everyday life in the (near) future. These issues are not only of great importance to scientists; they will have great impact on the whole of society and are therefore termed socio-scientific issues (SSI) (Kolstø, 2001; Zeidler et al., 2002). An important factor of scientific literacy is the ability to negotiate these socio-scientific issues and make informed decisions regarding them (Sadler, 2002, 2004). In examining previous research on how these issues can be incorporated into science curricula and classroom practice, we found that most research has been done on students' reasoning about these complex issues with inherent social implications (see Sadler & Zeidler, 2005;

Zeidler & Keefer, 2003; Zeidler et al., 2005). It has been suggested that SSI are taught most effectively through argumentation in the classroom (Conner, 2000; Steele & Aubusson, 2004). This requires subject matter that provides a meaningful, rich source of dilemmas for students to consider, such as cancer (Conner, 2000). The science module focused on several dilemmas of biotechnology relevant to the students' lives, such as family, lifestyle choices and preventive treatments, which were linked to knowledge of genetics in general as well as to biotechnology. The nature of the topic therefore provided students the opportunity to think about and discuss this socio-scientific issue.

The five design principles described are derived from science education literature. The empirical basis, however, is rather weak. The research area is dominated by qualitative and small-scale studies and there is a lack of (quantitative) experimental research in this area with regard to the effectiveness of the proposed design principles in classroom settings. The nature of most of the studies means that no clear conclusion can be drawn regarding the possible effects of such a learning arrangement on scientific literacy. It remains unclear whether, for example, more critical attitudes towards biotechnology have been elicited and whether they are based on a broader understanding. The combination of the design principles described here seems to promote scientific literacy but more evidence is needed. The present study attempts to answer some of the questions left unanswered by performing a quasi-experimental study using the new Dutch science module "Read the language of the tumour".

1.4. Research question and hypotheses

The main purpose of this study was to investigate the effects of the science module on the development of the attitudinal aspects of students' scientific literacy towards modern biotechnology. As previously described, the majority of students could be labelled as less scientifically literate in this particular field; a poor cognitive base combined with unclear opinions. The question was to what extent the science module could bring about more balanced and decisive attitudes.

The research question can be phrased as follows:

What is the effect of the science education module on attitudes of secondary school students towards modern biotechnology?

The following central hypothesis guided this study:

The science module has a more positive effect on the development of students' attitudes than regular science classes.

If the module was successful, the low scientific literacy group enhanced their knowledge base as well as their awareness of genomics. Consequently, they would either move to the group of 'confident supporters' or become more critical in their opinions and move to the 'concerned sceptics' group. More specifically, we expected to observe the following changes in the attitude post-test compared to the pre-test and the control group:

a) A smaller percentage of students in the 'not sure' group;
b) A smaller percentage of students in the 'not for me' group;
c) A larger percentage in the 'confident supporter' group;
d) A larger percentage in the 'concerned sceptic' group.

Apart from possible changes in group membership, we will also examine the effects of the science module on the different factors in each of the three attitude components. For instance, can changes be detected in scores on biotech knowledge in the cognitive component (see Table 1)? We implemented a pre-test – post-test experimental design to examine these hypotheses. The experimental condition consisted of students who, besides their regular biology classes on genetics and biotechnology, participated in the science module. The control condition included students who did not participate in the science module but only followed the regular biology curriculum on genetics and biotechnology.

2. Method

2.1. Participants

A total of 386 students (51.5% male) from 17 classrooms (year 11–12) from ten secondary schools in the Netherlands participated in the study. Twenty-one respondents were excluded from further analysis because of incomplete pre- or post-test data or outlier scores. Therefore, the total dataset included 365 respondents. The average age of the participating students was 16. Schools in the experimental condition were randomly selected from all schools participating in the DNA-lab project. Schools in the control condition were randomly selected from a general list of all Dutch secondary schools. In order to correct for possible effects of background variables, we selected schools that were comparable in terms of (a) the percentage of students with immigration and religious backgrounds, (b) students' socio-economic background characteristics and (c) the period in which the regular biology lessons on the subject of genetics were taught.

2.2. Research design

Pre- and post-tests were administered to students in the experimental and the control condition. Table 2 illustrates the design of the study. Students in the experimental condition received practical workbooks with explanations, instructions and assignments. Teachers received instruction manuals, including practical instructions and teaching guidance. Students in the control condition completed the pre- /or post-test, but did not

Table 2. Design of the study

		Attitudes pre-test	Experimental science module	Attitudes post-test	Number of respondents[1]
Experimental groups	Experimental group 1 (case study)	√	√	√	75 (4 groups)
	Experimental group 2	√	√	√	100 (4 groups)
	Experimental group 3	-	√	√	38 (2 groups)
Control groups	Control group 1	√	-	-	88 (4 groups)
	Control group 2[2]	-	-	√	64 (3 groups)

[1] Numbers of respondents can vary between pre- and posttest, as some students did not complete both questionnaires.
[2] Experimental condition 1 (case study) differs from experimental condition 2 in the sense that in this particular group of students, in addition to the administration of "pre- and post- attitudes tests", interviews were held with 16 students and classroom practice was observed. The results of these data will be reported in a subsequent article.

participate in the science module. These students attended regular biology lessons on the subject of genetics, which included lessons on modern biotechnology.

For reliability reasons (see the requirements) we made a distinction between three experimental groups and two control groups. Experimental group 1 (case study) differs from experimental group 2 in the sense that in this particular group of students, in addition to the administration of 'pre- and post-attitude tests', interviews were held with 16 students and classroom practice was observed.

To determine the effects of the science module, the following requirements had to be met:

1. The different groups of students needed to have the same starting point, as measured by the attitudes-pre-test.
   The results of the chi-square test showed that there was no statistically significant difference between the pre-test scores for all experimental and control groups (see Appendix I, Table a).
2. The possible impact of the attitudes pre-test experience on learning during the module, and consequently on the attitudes post-test needed to be ruled out.
   Therefore, we compared the post-test scores of the experimental 2 group (pre-test, treatment and post-test) and the experimental 3 group (no pre-test, treatment and post-test).The results showed there was no statistically significant difference between these two groups (see Appendix I, Table b).
3. The possible intervention effect due to the researcher's presence in the case-study classes should be accounted for.
   To exclude this possibility, we performed a chi-square test comparing the post-tests of the case study group (experimental 1) and the post-tests of the experimental 2

group. The results showed no significant differences between these two different groups (see Appendix I, Table c).

4. External incidents that affect the post-test should also be considered. For example, if during the time of the science classes geneticists found a cure for cancer by genetically modifying cells, this discovery could affect students' attitudes towards genomics and override the effect of the science module.

   For this reason, we analysed the results of the pre-test of control group 1 with the post-test of control group 2. No statistically significant difference could be established between these two control groups (see Appendix I, Table d).

Analyses showed that all requirements were met. The results of the chi-square tests are shown in the Appendix I. Therefore, we conclude that differences between conditions and between pre- and post-tests cannot be ascribed to design effects.

2.3. Instrument

To measure students' attitudes towards biotechnology, we used a previously developed questionnaire based on the general tripartite theory of attitudes (see Klop & Severiens, 2007). The first section of the instrument was designed to obtain (socio-) demographic information about the students (only in pre-test). The second and third parts of the instrument included four categories of items: knowledge items, cognitive evaluation items (beliefs), affective evaluation items and behavioural intention items (see Table 1, and we refer to Klop & Severiens, 2007 for a detailed description of the development of the instrument). Based on principal component analyses, several distinct and independent cognitive, affective and behavioural factors were found, as described in Table 1.

Cluster analysis resulted in the four different attitudes, as described previously; 'confident supporter', 'concerned sceptic', 'not sure', and 'not for me' (see Figure 2).

2.4. Analyses

To check the central hypothesis of the study, cluster membership of students in the pre-test were compared to cluster membership in the post-test, and experimental groups were compared to control groups. Because of the nominal measurement level of the dependent variable (cluster membership), the comparison is performed using chi-square tests. This test compares the distribution of students before the module to the distribution after the module, as well as possible significant differences between the experimental and control condition.

3. Results

The results of the comparison of the experimental groups with the control groups are presented first. Secondly, the results regarding the post-test compared with the pre-test within the experimental groups are described. We conclude this section with an analysis of the changes concerning the attitude components.

3.1. Comparison of experimental groups and control groups

Using a chi-square test, the post-tests of the experimental groups (1, 2, and 3) and the post-test of the control groups (which received no treatment) were compared. A significant difference of distribution of students in the four attitude clusters was found between the experimental and control groups in the post-test-scores χ^2 (3, N = 348) = 9.53, p < .05 (see Table 3). The greatest differences could be found in the percentage of 'confident students' in the experimental group versus those in the control group (43.9% vs. 30.3%).

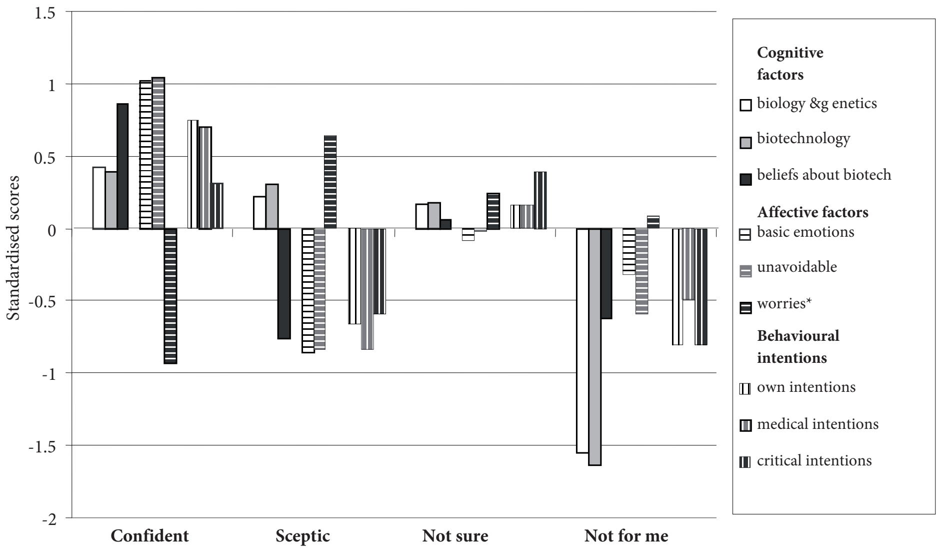


Figure 2. K-means cluster analysis of the attitude-pre-test-scores of 327 secondary school students, combined with the dataset of the previous attitude-test scores[1]
Confident supporters (n = 113), concerned sceptics (n = 66), not sure's (n = 123) and not for me's (n = 25). Scores are standardised values.
*Negative score on "worries-factor" indicates fewer worries about modern biotechnology.

[1] Cluster analyses on the data of the pre-tests showed slightly different clusters compared to the results in our former study, due to different background characteristics of the current dataset. Because our former study (Klop & Severiens, 2007) was based on a representative sample of students in terms of levels of education and the present study was based on the pre-higher education tracks only, the clusters as observed in the former study serve as a starting point for the present study. To maintain this particular composition, we combined the current dataset with the dataset of the previous study and performed cluster analyses on this larger dataset. These analyses resulted in the four originally observed clusters (figure 2). In this way, the students in the present study are assigned to one of the four original clusters.

Table 3. Result of Chi-Square test for comparison between post-test scores of experimental groups and post-test scores of control groups

		Clusters post-test				Total
		Confident (n)	Sceptic (n)	Not sure (n)	Not for me (n)	(N)
Experimental condition	Treatment	43.9% (86)	14.3% (28)	40.3% (79)	1.5% (3)	100% (196)
Control condition	No treatment	30.3% (46)	18.4% (28)	46.1% (70)	5.3% (8)	100% (152)

Chi-Square= 9.53; df = 3; Asymp. Sig. (2-sided) $p < .05$.

and between the 'not sure students' in the experimental group and the 'not sures' in the control group (40.3% vs. 46.1%, see Table 3).

The first three hypotheses can be confirmed; 1) At the end of the science module, there were significantly more students in the 'confident' group and 2) less in the 'not for me' group, compared to the control group. 3) The percentage of students in the 'not sure' group was somewhat smaller in the experimental groups (40.3% versus 46.1%). The fourth hypothesis, that there would be more students in the 'sceptics' group, could not be confirmed. There were even somewhat more sceptics in the control condition (14.3% versus 18.4%).

3.2. Comparison of pre- and post-tests within experimental conditions

A comparison was made between 'attitude cluster membership' before and after the science module within experimental groups. This comparison shows the possible changes in distribution of students over the four attitude clusters. Table 4 presents the results of the chi-square analyses, showing whether shifts in the distribution are statistically significant.

We hypothesised a decrease of students in the 'not sure' group. In the pre-test, 35.1% of students belonged to the 'not sure' group. In the post-test, this group has grown slightly to 37.1%. Therefore, the first hypothesis must be rejected.

The majority of this 37.1% belonged to the same cluster at the pre-test (41.1%, see the percentages column in Table 4), but a considerable percentage originated from the 'concerned sceptics' cluster (26.8%). Another part of the post-test 'not sure' cluster consisted of students who initially belonged to the 'confident supporter' (21.4%) and 'not for me' groups (10.7%).

The second hypothesis, a smaller percentage of students in the 'not for me' group, can be confirmed. There was a decline of 6.0% in the pre-test to 2.0% in the post-test. Of the three students in the 'not for me' group, two started out as 'not for me' students and one came from the 'not sure' group (see Table 4).

According to hypothesis 3, the percentage of students in the 'confident supporter' group should increase. The group of 'confident supporters' increased from 39.1% in the pre-test

Table 4. Results of Chi-Square test for comparison of cluster distribution of the students based on pre- and post-test scores of experimental groups

			Cluster post-test				Total
			confident	sceptic	not sure	not for me	
Cluster pre-test	confident	Count	46	1	12	0	59
		% within cluster at post-test	63.0%	5.3%	21.4%	0.0%	
		% of Total	30.5%	0.7%	7.9%	0.0%	39.1%
	sceptic	Count	3	12	15	0	30
		% within cluster at post-test	4.1%	63.2%	26.8%	.0%	
		% of Total	2.0%	7.9%	9.9%	0.0%	19.9%
	not sure	Count	23	6	23	1	53
		% within cluster at post-test	31.5%	31.6%	41.1%	33.3%	
		% of Total	15.2%	4.0%	15.2%	0.7%	35.1%
	not for me	Count	1	0	6	2	9
		% within cluster at post-test	1.4%	0.0%	10.7%	66.7%	
		% of Total	0.7%	0.0%	4.0%	1.3%	6.0%
	Total	Count	73	19	56	3	151
		% within cluster at post-test	100%	100%	100%	100%	
		% of Total	48.3%	12.6%	37.1%	2.0%	100%

Chi-Square= 76.19; df = 9; Asymp. Sig. (2-sided) p< .00.

to 48.3 % in the post-test. Hypothesis 3 can therefore be confirmed. Sixty-three per cent already belonged to this cluster at the start of the module and 31.5% initially belonged to the 'not sure' cluster, 4.1% were 'concerned sceptics' and 1.4% 'not for me's' (see Table 4).

Finally, hypothesis 4 must be rejected. A higher percentage of students in the 'concerned sceptic' group was not observed. The percentage of students in this group even decreased from 19.9% to 12.6%. More than half of them remained sceptics (63.3%). The other 36.7% consisted mostly of students who initially belonged to the 'not sure' group (31.6%) and a small part of the 'confidents' group (5.3%) (see Table 4).

3.3. Effect of science module on attitude components

A remarkable result from the analyses comparing pre- and post-tests concerns the increase of the 'not sure' cluster. Contrary to our expectations, a reasonable number of 'sceptics' as well as 'confidents' ended up no longer being sure what to think of modern biotechnology. Does this result indicate a decrease in scientific literacy? We examined the effects of the science module on the different attitude factors, by conducting pairwise t-tests on each of the attitude factors (see Table 2 for a description of all factors). First, we examined the attitudinal changes of the entire experimental group and subsequently, of the post not sure group. We also examined in more detail why students changed from being confident or sceptical to being unsure. The results are shown in Tables 5 and 6.

The results comparing the mean pre-test scores to the mean post-test scores of the students in the experimental condition revealed an overall significant improvement on two of the three factors measuring the cognitive component; knowledge of biotechnological applications, $t(150) = -2.90$, $p < .001$ and beliefs, $t(150) = -3.01$, $p < .001$.

There was also an increase in average scores on two of the three factors that measured the affective component; unavoidable, $t(150) = -3.01$, $p < .001$ and worries, $t(150) = 3.00$, $p < .001$ (reversely coded, see Table 5). These results suggest that the students showed a significant improvement in scientific literacy in terms of their knowledge base and positive awareness of genomics. However, no significant movement towards a more critical stance could be established, explaining the rejection of the fourth hypothesis (a larger percentage in the 'concerned sceptics' group).

Table 5. Mean attitude component scores for all participants on the experimental condition; obtained t- and significance of differences following paired sample analysis

		Paired Differences				
Attitude factors		Mean difference	SD	t	df	Sig. (2-tailed)
Pair 1	bio&gen pre - bio&gen post	-.00	.30	-0.33	150	.75
Pair 2	biotech pre - biotech post	-.03	.11	-2.90	150	.00
Pair 3	beliefs pre - beliefs post	-.13	.55	-3.01	150	.00
Pair 4	basic emotion pre - basic emotion post	.05	.47	1.26	150	.21
Pair 5	Unavoid. pre - unavoid. post	-.13	.51	-3.01	150	.00
Pair 6	worries pre - worries post	.17	.68	3.00	150	.00
Pair 7	own intention pre - own intention post	-.07	.66	-1.21	150	.23
Pair 8	med. intention pre - med. intention post	-.01	.72	-0.14	150	.89
Pair 9	crit. intention pre -crit. intention post	-.06	.67	-1.05	150	.30

Secondly, t-tests were used to detect the mean differences between pre- and post-test scores of the final 'not sure' students coming from the other three attitude clusters (see Table 6 for the results).

For the 'confident supporters' turning into 'not sures' there was a significant effect on the behavioural factors. The students showed less intentions of consuming when there was a personal benefit to gain (own intentions), $t(11) = 2.39$, $p < .05$. The intentions of using medical applications such as genetic tests, also declined, $t(11) = 2.22$, $p < .05$ and consuming intention under critical or environmental conditions (e.g., more environmen-

Table 6. Mean attitude factor scores for participants in post-module 'not sure cluster'; obtained t-value and significance of differences following paired sample analysis

Not sure cluster (post-test)	Attitude factors		Mean difference	Std. Deviation	t	df	Sig. (2-tailed)
Pre-test Confident supporters (n= 12)	Pair 1	bio&gen pre - bio&gen post	.04	.13	1.05	11	.32
	Pair 2	biotech pre - biotech post	-.04	.11	-1.15	11	.27
	Pair 3	beliefs pre - beliefs post	.28	.66	1.48	11	.17
	Pair 4	basic emotion pre - basic emotion post	.40	.61	2.29	11	.04
	Pair 5	unavoid pre - unavoid post	.23	.55	1.46	11	.17
	Pair 6	worries pre - worries post	-.32	.58	-1.89	11	.09
	Pair 7	own intention pre- own intentions post	.38	.56	2.39	11	.03
	Pair 8	med. intention pre- med. intention post	.40	.62	2.22	11	.04
	Pair 9	crit. intention pre - crit. intention post	.25	.38	2.28	11	.04
Pre-test Concerned sceptics (n=15)	Pair 1	bio&gen pre - bio&gen post	-.03	.11	-1.11	14	.29
	Pair 2	biotech pre - biotech post	-.02	.10	-0.67	14	.52
	Pair 3	beliefs pre - beliefs post	-.23	.60	-1.47	14	.17
	Pair 4	basic emotion pre - basic emotion post	-.19	.39	-1.82	14	.09
	Pair 5	unavoid pre - unavoid2	-.38	.42	-3.51	14	.00
	Pair 6	worries pre - worries post	.59	.56	4.04	14	.00
	Pair 7	own intention pre- own intentions post	-.40	.72	-2.16	14	.05
	Pair 8	med. intention pre - med. intention post	-.32	.85	-1.44	14	.17
	Pair 9	crit. intention pre - crit. intention post	-.42	.67	-2.43	14	.03

Not sure cluster (post-test)	Attitude factors		Mean difference	Std. Deviation	t	df	Sig. (2-tailed)
Pre-test Not sure's (n=23)	Pair 1	bio&gen pre - bio&gen post	.03	.15	0.86	22	.40
	Pair 2	biotech pre - biotech post	-.00	.12	-0.09	22	.93
	Pair 3	beliefs pre - beliefs post	.00	.34	0.00	22	1.00
	Pair 4	basic emotion pre- basic emotion post	-.01	.36	-0.13	22	.90
	Pair 5	unavoid pre - unavoid post	-.19	.44	-2.07	22	.05
	Pair 6	worries pre - worries post	-.02	.45	-0.18	22	.86
	Pair 7	own intention pre- own intentions post	.07	.49	0.68	22	.51
	Pair 8	med. intention pre - med. intention post	.35	.60	2.77	22	.01
	Pair 9	crit. intention pre-crit. intention post	.03	.38	0.37	22	.72
Pre-test Not for me's (n=6)	Pair 1	bio&gen pre- bio&gen post	-.02	.15	-0.25	5	.81
	Pair 2	biotech pre - biotech post	-.17	.10	-4.45	5	.01
	Pair 3	beliefs pre - beliefs post	-.37	.32	-2.80	5	.04
	Pair 4	basic emotion pre - basic emotion post	-.39	.62	-1.51	5	.19
	Pair 5	Unavoid. pre-unavoid. post	-.49	.59	-2.03	5	.10
	Pair 6	worries pre - worries post	-.23	.63	-0.91	5	.40
	Pair 7	own intention pre - own intentions post	-.40	.62	-1.58	5	.18
	Pair 8	med. intention pre - med. intention post	-.38	.98	-0.93	5	.39
	Pair 9	crit. intention pre - crit. intention post	-.56	.66	-2.07	5	.09

tally friendly) also declined, $t(11) = 2.28$, $p < .05$ (see Table 6). Apparently, a more reserved position towards behavioural intentions made these students change to 'not sure'.

A clear shift in affection was observed in the 'concerned sceptics' group. The expressed worries towards biotechnology declined, $t(14) = 4.04$, $p < .001$ (reversely coded) and feelings of biotechnology as an unavoidable process became stronger, $t(14) = -3.51$, $p < .001$ (see Table 6). The pre-sceptics also showed a more positive stance towards behavioural intentions, except for medical intentions (own intention, $t(14) = -2.16$, $p \leq .05$; critical intentions $t(14) = -2.43$, $p < .05$, see Table 6). Apparently, with a more positive affective and intentional standpoint, these students lost a little of their concern and scepticism and consequently, moved to the 'not sure' group.

As far as the 'not for me's' are concerned, a significant improvement on the scales measuring the cognitive component was observed. There was significant progress on content knowledge of biotechnology and its applications, $t(5) = -4.45$, $p < .05$ and a more positive beliefs towards modern biotechnology, $t(5) = -2.80$, $p < .05$. By changing into 'not sures', this group was still not able to make up their minds completely but did show a more solid cognitive base.

4. Discussion

Being scientifically literate means understanding the world we live in and being interested in it, taking part in discussions of and about science and being sceptical and questioning claims made by others about scientific matters, so that we can make informed decisions about the environment and personal health and well-being (Goodrum et al., 2001). In our view and as far as modern biotechnology is concerned, scientifically literate people have an accurate knowledge base on basic biological and genetic concepts, display an affective reaction of concern or comfort towards biotech issues and have clear ideas on how to behave or make decisions when confronted with modern biotechnology (in accordance with Millar, 2006). In other words, having a well-considered confident or sceptical attitude towards modern biotechnology (Klop & Severiens, 2007). The question is how 'scientific literacy' can be promoted; in what ways can science education encourage students to learn about so-called socio-scientific issues and develop their own personal opinions?

This study examined the effects of an innovative science module on the attitudes of secondary school students towards modern biotechnology. We made use of a new Dutch science module for the upper levels of secondary education. The socio-scientific topic of the science module was genomics and cancer, the underlying design principles inspired by a social constructivist perspective on learning. We hypothesised that if the module was successful in developing scientific literacy, more students would move to the group of 'confident supporters' or become more critical in their opinions and shift to the 'concerned sceptics' group and consequently, fewer students would be found in the 'not sure' or 'not for me' clusters.

Based on the combination of design principles and the socio-scientific and relatively new subject matter (Conner, 2000; Sadler, 2002; Zeidler et al., 2005), we had reason to believe that even a small module could bring about some changes in attitudes.

Changes were indeed observed and our hypotheses were partly confirmed. The module did result in a larger group of confident supporters, also in comparison with the control condition. The expected increase in the numbers of 'concerned sceptics' was not observed. The 'sceptics' group even decreased in size. We offer three explanations for this finding.

The first explanation concerns the number of lessons in the module: the changes were brought about in only four lessons. Students might have been overwhelmed by the (in particular pro-genomics, see next paragraph) module and therefore adopted ways of thinking about modern biotechnology without having time to think critically about its construction.

Elaborating on the first explanation, we give a second reason for the growth in the 'confident supporter' group, and the reduction in the 'concerned sceptics' group. There may have been a possible overexposure of the positive sides of modern biotechnology during the lessons. Although critical references were offered on several societal issues, the emphasis of the module was on the benefits of cancer research using biotechnology. For that reason, the likelihood of students changing into 'confident supporters' is greater than the likelihood of their turning into 'concerned sceptics'. From the perspective of biotech research institutions or universities, this might be seen as a positive side effect but it is certainly not the purpose of teaching for scientific literacy. Therefore, we would like to argue that in the interests of fostering scientific literacy among students, science education modules such as the one described in the present study should focus on all aspects of genomics, the advantages as well as the disadvantages, the technical as well as the ethical.

A third explanation for the decrease in the 'concerned sceptics' group might be the quality of the fourth lesson of the module. Observational data gathered during the science module and other research on this science module suggested that many teachers omitted (most of the) reflection activities (see Knippels, Rijst, & Severiens, 2006, for a general evaluation of the science module; Waarlo, 2007). This means that a relatively large group of students was not invited to think critically about their newly acquired knowledge and feelings and the discussions they had had with their peers on the subject. These are, however, important factors in developing scientific literacy (Sadler & Zeidler, 2004; Zeidler et al., 2005; Zeidler et al., 2002). In most subjects in secondary education, relatively little attention is devoted to reflection on the learning content (deep understanding and insight) and reflection on students' own thinking and learning processes (meta-cognition) (Volman & ten Dam, 2000). These explanations lead to a recommendation for improving the science module: if more time is spent and a greater emphasis is placed on reflection activities, it may help students to move from the 'not sure' group to the 'sceptics' group.

An unexpected finding in the present study concerned the substantial group of students that moved from the 'confident supporter' group, or the 'concerned sceptic' group, to the 'not sure' group. Our previous study has demonstrated that this particular group of students has a rather unclear attitude towards modern biotechnology; they are not sure what to think, feel, or do with it and their overall knowledge of the subject is rather poor. This may be a perfectly understandable position for the 'average teenager'; we expected that the science module would give them a more solid foundation on which to base their attitudes and that they would demonstrate more certainty about their own opinions. T-test analyses showed that this partially occurred. All students in the experimental condition showed a significant improvement in the cognitive and affective component of scientific literacy, as far as their knowledge base and positive awareness of genomics is concerned. This also implies that the meaning of 'being not sure' after the module has changed. Especially since several 'confident supporters' and 'concerned sceptics' made a transition towards 'not sure'. During the science module, students acquired new knowledge, learned about new dilemmas, discussed these dilemmas with peers and did hands-on work that was supervised by students from a university, etc. In hindsight, it is understandable that due to all these experiences and the increase in their knowledge level, some of these students started questioning their own views and behavioural intentions. In that sense, these students have become less sure about what to think. In our instrument, we made no (quantitative) distinction between ambivalent or questioning responses and indifferent responses (Gardner, 1987). Future research should therefore include a measure of ambivalence.

In summary, we have suggested that the science module could be successful in promoting scientific literacy among secondary school students. The science module indeed helped students to become somewhat more scientifically literate due to the improvement of their knowledge base and display of affective reactions towards biotech issues. Nevertheless, students were insufficiently invited to think critically about their newly acquired knowledge, feelings and the discussions on the subjects that went on in the classrooms. This resulted in an under-representation of critical and sceptical students at the end. Besides, when socio-scientific issues are discussed only one-sidedly, for example by leaving out the ethical dilemmas, students are again not invited to take a critical stance.

All students must be aware of the complexity of this expanding scientific discipline so they will be able to participate and be sceptical and questioning about scientific matters and to make informed decisions for personal, social and global benefits.

Acknowledgement

We would like to thank the Centre of Cancer and Genomics, especially Marc van Mil and Annelies Speksnijder, for allowing us to use their science module and data from the participating schools.

Appendices. Meeting the requirements

Initial differences

Table a: Results of Chi-Square test for comparison between pre-test scores of experimental and control groups

		Clusters				Total (n)
		Confident	Sceptic	Not sure	Not for me	
Experimental condition	Experimental 1, case study	33	10	28	4	75
	Experimental 2	33	23	35	9	100
	Control group 1	30	23	29	6	88
	Control group 2[3]	17	10	31	6	64
Total		113	66	123	25	327

Pearson Chi-Square 11.31, df 9, Asymp. Sig. (2-sided) p = .26

Effect of the pre-test

Table b: Results of Chi-Square test for comparison between post-test scores of experimental groups

		Clusters				Total
		Confident	Sceptic	Not sure	Not for me	
Experimental condition	Experimental 2; Pre-test and post-test	42.2%	13.3%	41%	3.6%	100%
	Experimental 3: only post-test	28.9%	21.1%	50%	0%	100%

Pearson Chi-Square 4.10, df 3, Asymp. Sig. (2-sided) p = .25

Intervention effect

Table c: Result of Chi-Square test for comparison between post-test scores of case-study groups and experimental groups

		Clusters post-test				Total
		Confident	Sceptic	Not sure	Not for me	
Experimental condition	Experimental 1; case study	56%	8%	36%	0%	100%
	Experimental 2	42.2%	13.3%	41%	3.6%	100%

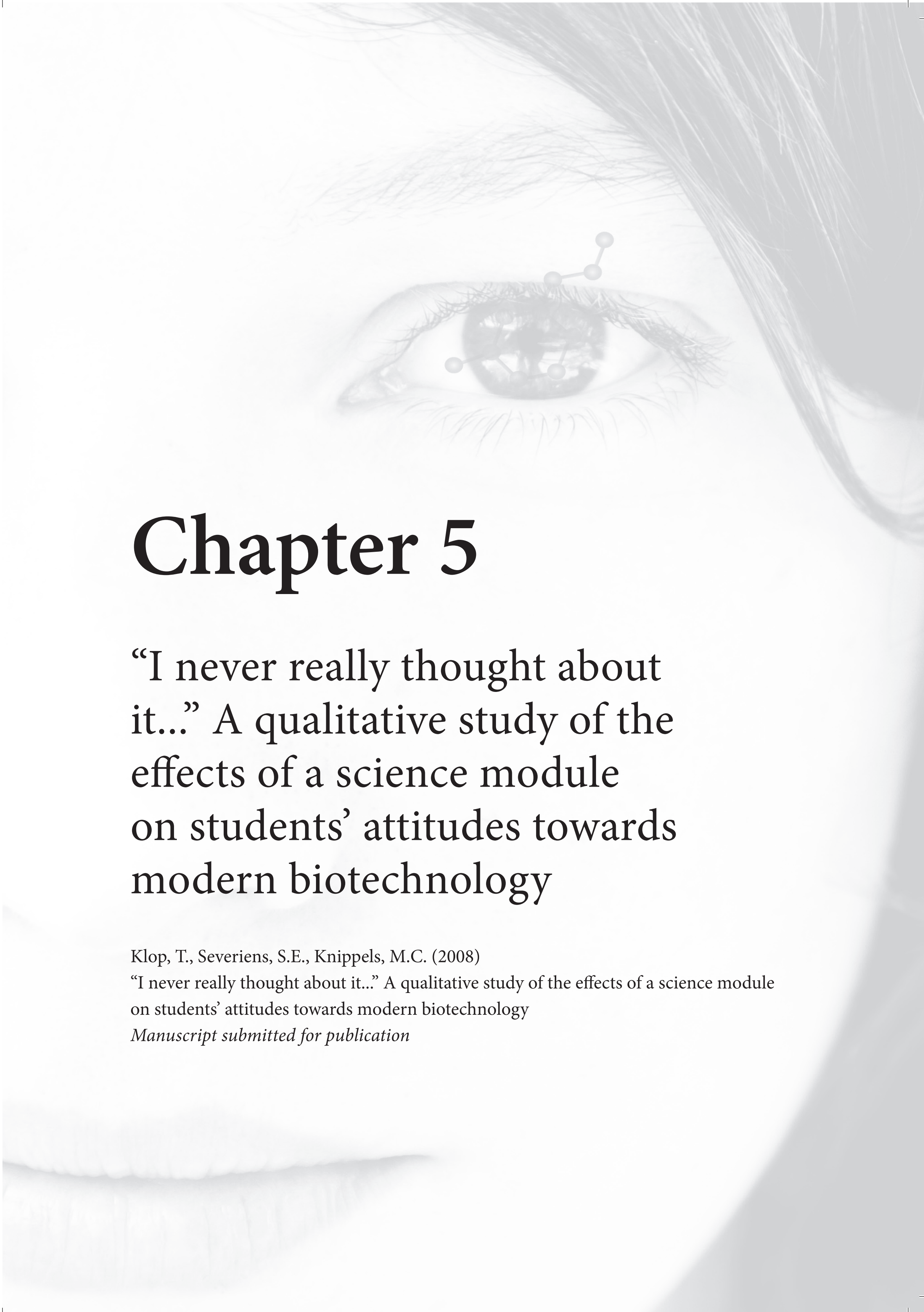
Pearson Chi-Square 5.52, df 3, Asymp. Sig. (2-sided) p = .14

External incidents

Table d: Result of Chi-Square test for comparison between pre-test scores of control groups (only pre-test) and post-test scores of control groups (only post-test)

			Clusters				Total
			Confident	Sceptic	Not sure	Not for me	
Control condition	Control 1; pre-test	% in condition	34.1%	26.1%	33%	6.8%	100%
	Control 2; post-test	% in condition	26.6%	15.6%	48.3%	9.4%	100%

Pearson Chi-Square 5.12; df 3; Asymp. Sig. (2-sided) p = .16



Chapter 5

"I never really thought about it..." A qualitative study of the effects of a science module on students' attitudes towards modern biotechnology

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Abstract

This case study investigated the effects of a science module on secondary school students' attitudes towards modern biotechnology. The module was designed to promote understanding and awareness of biological, social and ethical issues associated with cancer and cancer research. Four secondary school science classes participated in the case study, of which sixteen students were interviewed on aspects of their attitudes towards modern biotechnology before and after the experimental science module. Pre- and post-attitude questionnaires, classroom observations, and pre- and post-module interviews were used to follow students' attitudinal changes. The results show a shift towards more positive and ambivalent attitudes. These findings suggest that besides the need to gain understanding and awareness, thinking through affective aspects as well as personal intentions are essential to foster a transition towards a more defined and well-founded attitude. Based on the results, implications for science education and future research are discussed.

1. Introduction

Modern biotechnology is the term used to incorporate the vast (and growing) range of techniques for modifying life forms for research (medical, environmental and agricultural) and commercial uses. The utilisation of modern biotechnology will ultimately alter our health care, industry and agriculture and consequently, will influence various aspects of our society as we know it (Gaskell et al., 2003; Kirkpatrick et al., 2002; Macer, 1992; Pardo et al., 2002; Waarlo et al., 2002). The increasing impact on everyday life requires a certain level of scientific literacy in the general public. Young people will need such knowledge in their future careers and in their daily lives as members of this fast changing society, to make personal and social choices about issues related to science and technology. Therefore, promotion of scientific literacy has been widely recognised as a major goal of science education (e.g. American Association for the Advancement of Science, 1989; Driver et al., 1996; Millar & Osborne, 1998; National Science Foundation, 1996). An important question is how science education may succeed in stimulating students to develop scientific literacy abilities.

This study aims to contribute towards answering this particular question. Using a case study design, this study examined the effects of an innovative science module aiming to stimulate scientific literacy (in particular concerning modern biotechnology or genomics). A first paper on this study (Klop, Severiens, & ten Dam, submitted) considered the results as shown by quantitative measures.

The aim of the present paper is to describe and explain the quantitative results in more detail, using questionnaires and interviews held with students before and after the module.

The study combines a theoretical framework regarding scientific literacy using the tripartite attitude theory. In the next paragraphs, we clarify this combination and summarise the quantitative results.

1.1. Scientific literacy and attitude theory

The term scientific literacy is increasingly being used to characterise the aim and purpose of school science education. However, not only is the term defined differently in different contexts (AAAS, 1989; DeBoer, 2000; Laugksch, 2000), the interpretations of scientific literacy abilities range from understanding lay articles in newspapers and popular magazines (Millar & Osborne, 1998) to the abilities of a semi-professional scientist (Hazen & Trefil, 1991; Thomas & Durant, 1987). With Millar (2006), we argue that the starting point of science education should be the aspiration to include scientific literacy competences that students need to be able to live and participate with reasonable comfort, confidence and responsibility in a society that is deeply influenced and shaped by the applications, ideas and values of science (Millar, 2006). This generally implies a set of cognitive, affective and behavioural abilities needed to function effectively in an increasingly complex and technology-dependent society, and to understand the essence of competing arguments on a given controversy (Bingle & Gaskell, 1994; Dimopoulos & Koulaidis, 2003; Jenkins, 1992; Miller, 1998). In order to examine the effects of science education on scientific literacy, we have focused on the development of these basic components of scientific literacy: cognition, affection and behaviour.

It is the particular combination of 'thinking, feeling and acting' that bears similarity to the attitude model described in the tripartite theory of attitude (Breckler, 1984; Chin, 2005; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960).

This model encompasses three basic attitude components: an affective, a cognitive and a behavioural component. The concept of attitude towards modern biotechnology can therefore be described as the product of 1) knowledge and beliefs about biotechnology (the evaluative and cognitive component), 2) experienced feelings and emotions about biotech issues (the affective component), and 3) behavioural intentions towards biotechnology and its applications, for example, buying GM food, taking a DNA test (the behavioural component).

Our line of reasoning is that when students have a reasonable knowledge base on basic biological and genetic concepts, they display a well-considered affective reaction towards biotechnological issues and they have clear ideas on how to behave or make decisions when confronted with modern biotechnology. In other words, when students have profound attitudes, they can be considered scientifically literate on the subject of modern biotechnology (American Association for the Advancement of Science, 1989; Goodrum et al., 2001).

Science education should therefore not only focus on scientific knowledge but also on understanding how science works, its contribution to and effect on society and how it will or can be important to our daily life. That is, science education should aim to teach students how to cope, in a reasoned way, with the effects of modern biotechnology (Sadler, 2002; Zeidler & Keefer, 2003; Zeidler et al., 2002).

1.2. Features of the science module

This article reports a study on the impact of science education on the attitudes of secondary school students. For this purpose, we used a new science module for the upper levels of secondary education, developed by the genomics research centre of excellence (CGC)[1]. The topic of the science module was genomics and cancer research; titled 'Read the language of the tumour' ('*Lees de taal van de tumor*'). A so-called mobile DNA lab

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[1] The Cancer Genomics Centre (CGC) is a strategic collaboration of research groups from the Netherlands Cancer Institute, the Erasmus Medical Centre, the Hubrecht Laboratory and the University Medical Centre Utrecht.

gives students the opportunity to encounter new and sophisticated research techniques. The module aims at students' acquisition of knowledge on the subject of genomics, by giving a realistic picture of genomic research. Moreover, it intends to stimulate the opinion forming and critical reflection of students towards genomics and its implications on society (Waarlo, 2007). In this manner, not only cognition is taken into account, but also affection and intentions of the students within the science class. Within this module, we identified five design principles with a social constructivist perspective on learning (for details see Klop, Severiens & ten Dam, submitted):

- Stimulate active learning
- Stimulating inquiry-based learning
- Using authentic tasks
- Stimulating reflection
- Using socio-scientific issues

The science module consisted of four lessons; an introductory lesson, two practical/hands-on lessons (in succession) and a reflection lesson (see Figure 1). This science module (the practical lessons) 'travelled' around secondary schools in the Netherlands.[2]

Lesson 1 Introduction	Lesson 2 "The genomics lab"	Lesson 3 "The genomics lab"	Lesson 4 Reflection

Figure 1. Design of the experimental science module

During the introductory and reflection lessons, the teacher him/herself provided instruction and guidance. The practical lessons, in a 'DNA lab setting' at school, were supervised by two trained students from the university. Teachers who signed up for the science module received a detailed teacher manual and workbooks for their students.

The introductory lesson included a brainstorming session and the opportunity to raise questions on the topics of cancer and cancer research. The lesson was designed to connect with students' prior knowledge of the subject matter, since students were already presumed to have at least some background knowledge and ideas about social or ethical matters relating to cancer and/or biotechnological research (*socio-scientific issues*). After activating prior knowledge and clarifying ideas or difficulties, students were invited to discuss their questions about and experiences with cancer and cancer research in small groups first and then in the whole class (*active learning* and *stimulating reflection*).

In the second and third lessons, students had to perform assignments in small groups in a genomics laboratory setting (two or three students), under the supervision of two

[2] The module was designed for science classes at the higher levels of secondary schools within the Dutch educational system.

university students. In this setting, using a hands-on approach, the students were invited to use real 'genomic techniques' (using *authentic tasks* and *inquiry-based learning*). This was an opportunity to visualise abstract biological concepts: observing preserved cancer tumours, extracting DNA out of a thymus gland (calf), and demonstrating defects in genes that can cause cancer by carrying out polymerase chain reaction (PCR) and gel-electrophoresis experiments. Combined with exploration and discussion of the relevance and complications of cancer research for patients, relatives and society, genomics was placed in a social and moral context (*inquiry-based learning* through *socio-scientific issues*).

A week after the lab lessons, during the fourth lesson, the students were supposed to reflect on their hands-on experience. They had to draw conclusions from the experiments and to complete a fictional counsel form that laboratory researchers use to write down their findings and conclusions. The students were given the role of researcher by having to give treatment recommendations to a doctor. They had to read non-specialist articles in class and reflect on their own questions formulated during the introductory lesson. There was room for ethical discussions so that the experiments could be placed in a broader, societal context and students could reflect on their own experiences, feelings, and thoughts (*stimulating reflection*).

1.3. Previous study

A quasi-experimental design was set up (for details see Klop, Severiens & ten Dam, submitted). A total of 365 secondary school students (in experimental and control groups) completed a pre- and/or post-test (questionnaire) in order to assess their attitudes towards modern biotechnology before and/or after participating in the science module (experimental condition) or before and/or after the regular biology classes on genetics and biotechnology (control condition). We refer to Klop & Severiens (2007) for a detailed description of the development of the questionnaire (see appendix I for an overview). Based upon their answering patterns on cognitive, affective and behavioural components, the participants were placed into four groups, reflecting either more or less scientific literacy abilities. The four attitude patterns discerned among the secondary school students were: 'confident supporters', 'concerned sceptics', 'not for me's', and 'not sures' (Klop & Severiens, 2007).

The 'confident supporters' were a positive, pro-biotechnology and well-informed group of students who seemed to welcome biotechnology in their daily lives. This group was considered 'more scientifically literate', based on our previously stated line of argument.

The 'concerned sceptics' were also a more scientifically literate group of students with a strong cognitive base. They tended to be more sceptical and concerned about biotechnology.

The smallest group, the 'not for me' students, was very negative about biotechnology. Their beliefs and affective reactions were very negative but they also displayed a lack of knowledge on the subject. Because of their poor cognitive base, this group was designated as less scientifically literate.

The last cluster, the so-called 'not sures' formed the largest group. Their views tended to be rather unclear; they were neither 'anti nor pro biotechnology' and their overall level of knowledge was somewhat moderate. This group did not meet the criteria of being very well scientifically literate either.

We hypothesised that if the module was successful in developing scientific literacy, more students would either move to the group of 'confident supporters' or become more critical in their opinion and move to the 'concerned sceptics' group and consequently, fewer students would be found in the 'not sure' or 'not for me' clusters.

This hypothesis was only partly confirmed. The module indeed encouraged students to become more scientifically literate but mainly in the 'positive' direction, resulting in a larger group of confident supporters within the experimental condition. However, the development towards a more literate and sceptical attitude was not found; the 'sceptics group' even declined just over seven per cent.

An unexpected finding was the relatively large percentage of students moving towards a 'not sure' attitude. Most of the 'not sure' students remained in the same cluster (41.1%), but a considerable number also came from the 'concerned sceptics' cluster (26.8%), the 'confident supporter' cluster (21.4%) and the 'not for me' group (10.7%).

In post-hoc analyses, the whole experimental group revealed an overall significant improvement on the cognitive component; suggesting that the students showed a significant improvement in scientific literacy in terms of their knowledge base. For the 'confident supporters' becoming 'not sure', significant differences were found in the behavioural component. A more reserved position towards behavioural intentions made these students change into 'not sure'. A clear shift in affection was observed in the 'concerned sceptics' group; especially the expressed worries towards biotechnology seemed to have declined. Apparently, with a more positive affective stance, these students lost a little of their concern and consequently, moved to the 'not sure' group. As far as the 'not for me's' were concerned, a significant improvement in the factors measuring the cognitive component could be observed. Although still not able to make up their minds completely, they seem to have taken a distinct step towards becoming more scientifically literate.

1.4. Aim of the present study

In our former paper, we showed the changes brought about by the science module in the attitude clusters based on quantitative measures. The purpose of this case study was to elicit the underlying explanations for the observed change in students' attitude, like that of the 'unsure group' and examine how students themselves interpreted their attitudes and attitude changes towards modern biotechnology. A qualitative case study approach was set up to answer the following research question:

How can the changes in students' attitudes after an innovative science module be interpreted and explained?

This study was performed with the intention of developing a greater understanding of the attitudes of students towards modern biotechnology and the effect of science education aimed at improving scientific literacy.

2. Method

2.1. Participants

Four secondary school science classes participated in the case study by answering the pre- and post-questionnaires, on the basis of which sixteen students were interviewed about aspects of their attitudes towards modern biotechnology before and after the experimental science module. The average age of the participating students was 16.

Data from the pre-test attitude questionnaire were used to select the students for in-depth interviews before, after the science module, and for observations during the module. Of each class, one 'not sure', one 'not for me', one 'confident supporter', and one 'concerned sceptic' student was selected. The group comprised nine girls and seven boys. Post-test results were used to determine changes in attitude components or attitude cluster among the participants. The names of the participants reported in this article are pseudonyms, to guarantee the anonymity of the participants.

2.2. Measures

To answer the research question, we used a case study design (Merriam, 1998) with an interpretive approach (Erickson, 1986; Gallagher, 1991, Stake, 2000) to examine the effects of the science module on students' attitudes towards modern biotechnology. Both qualitative (interviews) and quantitative (questionnaire) data were collected in a pre- and post-test design. Semi-structured interviews were held with the 16 selected students before and after the science module and field observations were made.

The interviews included questions on the different components of their attitudes. The semi-structured design ensured that all respondents were confronted with a set of core questions (Kolstø, 2001). The interviewer used open questions, which enabled respondents to demonstrate their unique way of looking at the world and to give their own definition of the situation (Silverman, 1993).

Each interview lasted about 30 minutes. Main issues were the respondents' explanation of their cluster membership (and possibly change of cluster after the module); what did they actually know, feel and think about modern biotechnology? Which of these aspects did they consider to be important? Other issues about the students' ethical perceptions on specific applications of biotech (cancer research) and their personal feelings towards it were also addressed.

The aim of the pre-test interviews was to elicit the personal narratives of the selected students on how they interpreted and explained 'their attitude cluster' and if they agreed with the cluster to which they were assigned (see 'validity of the attitude questionnaire').

The interviews after the science module were used to elicit clarifications and explanations for the changes of attitude clusters or attitude compositions (why do 'sceptics' turn into 'not sures', as seen in the previous study). All interviews were transcribed verbatim.

2.3. Analyses

The formal analytical process began with a review of all transcripts of the interviews, during which units of data (or arguments) were coded. Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study and are used to retrieve and organise data (Miles & Huberman, 1994). The general purpose of this analysis was to identify students' interpretations of the phenomenon of modern biotechnology, with the basic attitude components (cognition, affection and behavioural intentions) as categories.

The coding process was performed in two steps. First, the transcripts were coded by attitude components (cognition, affection, behavioural intentions and ethical considerations). Second, the coding process focused on the types of reactions within each component. The factors of the attitude instrument (see appendix I) were used as a framework for this second coding process. For example, an affective reaction could refer to a basic emotion, a feeling of 'unavoidability', referring to worries or to another emotional interpretation. This coding process was performed by all the authors of this paper, to establish inter-rater reliability.

2.4. Implementation

In order to be able to judge the process of attitude change in relation to the science module, the level of implementation of the module should be considered (van den Akker, 1988). The classroom observations and interviews with students gave a clear picture of the extent to which the module was implemented as intended.

Observations during the first lesson revealed that although some small group discussions took place, a full class discussion was not realised. Teachers seemed to easily fall back on teacher-directed instruction. Some of the students confirmed this observation, as Rik (Table 1) pointed out: 'W*ell, the discussion did not really work out, since no one really speaks up in our class*.' These notes cast doubt on the implementation of the whole class discussions as an important activity to promote active learning.

As the lab session (second and third lesson) was directed and performed by university students who were trained for these lessons, it was implemented as envisaged by the designers. However, observation of this part of the module displayed an overexposure of the positive sides of modern biotechnology. Even though critical references were offered on several societal issues, most of the module showed the benefits of using biotechnology for cancer research. For this reason, it is questioned if all the socio-scientific issues of cancer research were addressed, thereby placing genomics in a social and moral context.

Nevertheless, all students stated that they enjoyed this part of the module the most. Especially the visualisation of abstract biological concepts (DNA, cancer, tumour and genes) and the hands-on activities, like PCR, stood out. As Sam put into words:

"Yes, I really enjoyed it. I really liked the fact that you could do things for yourself, you know, explore it on your own. I have seen many things that you would normally never see. I mean, DNA, the fact that I saw DNA! I never really knew what it looked like but it looks just like snot. I thought it was so small; you wouldn't be able to see it. (…)"

The fourth lesson was not implemented in all four classes, as was envisaged by the original module design. Our observation data and other research on this science module suggest that most teachers omitted large parts of the reflection activities (Knippels, Rijst & Severiens, 2006; Waarlo, 2007). The activities were limited to drawing conclusions and writing down the findings from the experiments and answering the questions formulated during the introductory lesson. This means that most of the students were not invited to place the experiment in a broader, societal context. They were not challenged to think critically about their newly acquired knowledge and feelings and the discussions they had had with their peers on the subject. This indicates that stimulating reflection, as one of the core design principles, was not fully realised for all students.

2.5. Validity of the attitude questionnaire

The sixteen interviewed students were asked to explain if and why they belonged to their particular cluster (see Table 1 for characteristic cluster quotations). Due to the abundance of collected data, it is not possible to describe all views and arguments expressed by the students about modern biotechnology. We have generally limited commentary to those views expressed by the majority and which are characteristic for the cluster sample (see Table 1).

All of the 'confident supporters' agreed that they belonged to this particular cluster. They claimed to know a great deal about modern biotechnology, to be very positive about it, and to have great faith in genomic research and researchers.

All the sceptical students indeed displayed a critical point of view. They were very aware of the benefits but for the greater part, of the possible negative side effects and risks of modern biotechnology. They also seemed a slightly reluctant towards the use of modern biotechnology in general.

Three out of four 'not sure' students agreed they were not sure what to think of biotechnology. They were neither pro nor anti-biotech. However, one student (Marjon) was more pronounced in her statements. Instead of being somewhat indifferent, she argued for being ambivalent; she could not make up her mind because according to her: '*modern biotechnology has good and bad qualities*'. Furthermore, a remarkable point within this group was that two out of four students indicated that their religion played a role in this indecision (Harold and Cees).

Table 1. Characteristic cluster-quotations of the 16 students in the pre- module interview categorized in attitude components.

Attitude components	Confident supporters	Not sures	Concerned sceptics	Not for me's
Cluster membership	Yes, I certainly agree. I see a bright future and then not only for me, but also for other people (…). I think this technology can only go forward. (Marijke)	I do not know what to think of it. I don't know ... you see, I'm a Christian and yes, what must one think, of these developments and what they're doing. (Harold) (…) for this reason you simply end exactly in the middle. It really counterbalances each other. Perhaps it is, though, a threat, but I know it is necessary. (Marjon)	I do not know if they're already certain that, for example, cloning is harmless, so.. And as long as I don't know, I think, well don't do it. I feel uncomfortable when something like that happens. (Remy)	Well, you know, I'm not really interested in it. (Sabrina) Well, I'm not completely against it, but my expectations are really not that high. I think it will get out of control one day. You see, it might be handy in the beginning, but at a certain point it will be misused, I think, those technologies. (Frans)
Cognitive component **Beliefs**	Yes, I thought it was rather easy, but the questions were really not that complicated. You hear about a lot of these things and then you remember it. (Rik) Of course, some things will fail, but hey, it's only going to be better, because you learn from your mistakes (…) (Marijke)	Yes, well I don't know exactly. It's that you take a nucleus, a thing out of the nucleus of one cell, a healthy cell, and put it in a sick cell and that's the way someone gets better. (Marjon) I think everything should be done to help people and make sure they lead better lives.(Sam)	I think modern biotechnology is with genetic modifying, or something like that, changing things… in genes or something. (Renee) Yeah, I know they can make food for Africa or so, or take away diseases, but well… I don't know, they will always make mistakes, and I guess my concern is stronger. (Remy)	Well, no, I'm not really interested. It has something to do with new developments or something, I thought, with experiments and all. (Karin) Well, I think it will be handy for diseases and things. But that's enough for me. I never really thought about it. (Karin)

Attitude components	Confident supporters	Not sures	Concerned sceptics	Not for me's
Affective component	No, I have no worries about cloning. If danger would occur, like things mutating into gigantic monsters, these problems are easy to solve. So no, it is not something we have to worry about. (Jona)	(On cloning) Well… to start with the most extreme example, suppose some kind of lunatic arises, some kind of dictator, with the same ideas as Hitler, about a perfect race. While in his eyes a perfect race is completely different than someone else's ideas. Of course, it is an extreme example. (Marjon)	Well, I have the feeling that people want to play God or something like that. I find that everything should be left the way it is.(…) (Esther)	No, but yeah,… on the other side, I don't know what intentions they have with it. So I do find it a bit scary. (Sabrina)
Behavioural intentions	Well, it's a way of improving human life; you get rid of weaknesses in humans, for example diabetes. That sure is very positive. (Jona).	Well, if it's really safe and it's there, why not. But I first want see scientific proof of its safety. So you won't get any diseases or genetic manipulation yourself. (Marjon)	I wouldn't eat GM corn, because actually they put this chemical stuff in it. I don't think of it as real corn, it's more fake corn. (Renee)	If it doesn't make me sick, why not, if it's already available. (Frans)
Predictive genetics		Of course, it sucks that you know you will get cancer, but on the other hand, you can take care of it in time. (Cees)	I don't want to know. I don't want to live differently, thinking all the time… oh within two years I'll be sick (…) (Remy)	
Ethical limits	I think the limit is when they start making real mutations. (Rik)	I don't know, whether you're dying of GM food or of starvation, I don't know where you should draw that line. (Marjon)	Everyone is unique and you should keep it that way. If you have some genetic disease, well, so be it. You'll just have to deal with it. (Esther)	I think boundaries will fade over time, for me that is a reason to take it slowly, consider if something is really necessary. (Frans)

The main reason for being a 'not for me' member among the four students was lack of knowledge and/or interest. Only one student (Frans) clearly explained that he had some serious concerns and fears about modern biotechnology, in addition to being badly informed (see Table 1).

Since all students agreed with their cluster membership, it can be concluded that the attitude test is a valid test in terms of its construct validity.

3. Results

This section describes the changes or developments of the basic attitudinal constructs of scientific literacy; cognition, affection and behaviour and ethical considerations[3] of the sixteen students towards biotechnology.

The changes in attitudes are described according to attitude cluster. Table 2 provides an overview of the attitude clusters and cluster changes of the participating students. An overview of the actual changes in each of the different attitude factors for each individual student is given in Table 3. The most remarkable changes within the four clusters are described and supported with quotes from the students given during the post-interview in Table 4.

Table 2. Attitude clusters and cluster changes of participating students, before and after the science module.

Attitude cluster	Pre-module	Post-module
Confident supporter	***n* = 4**	***n* = 5**
	Jan	Jan
	Marijke	Marijke
	Jona	Jona
	Rik	Rik
		Sam*
Concerned sceptics	***n* = 4**	***n* = 2**
	Renee	Renee
	Sarah	Sarah
	Remy	
	Esther	
Not sure	***n* = 4**	***n* = 9**
	Sam	
	Harold	Harold
	Marjon	Marjon
	Cees	Cees
		Remy*
		Esther*
		Sabrina*
		Karin*
		Frans*
		Maria*
Not for me	***n* = 4**	***n* = 0**
	Sabrina	
	Karin	
	Frans	
	Maria	

*Changed clusters are indicated by an asterisk.

[3] This component is not included in cluster analyses and cluster assignment.

3.1. Confident supporters

As described in former papers (Klop & Severiens, 2007; Klop, Severiens & ten Dam, submitted), the group of confident supporters is identified as a more scientifically literate group and proved to be the most stable group as far as their attitude was concerned.[4] When asked about their attitudes after the science module, none of the interviewed students thought they had changed their views towards biotech. Two students stated to have become even more confident and hold even more positive views towards modern biotechnology.

This positive group of students greatly appreciated all parts of the science module and were in favour of receiving science education in this way. They showed themselves to be enthusiastic and concentrated participants.

Cognition (knowledge and beliefs)

All four students started out with a good knowledge base on basic biological and genetic concepts but still indicated to have learned much about cancer and biotechnology. As the quotations of Marijke illustrates:

> *"Yes, I've learned very much. I really think that, I mean, if I look at myself a month ago, I hardly knew anything about it. Yes, I knew the term cancer and that it's a disease but that's about it. And a lot of people will never know any more than that!"*

All but one student (Jan) scored higher on the knowledge part of the attitude test (see Table 3). Their beliefs about modern biotechnology were already very positive before the module. Table 3 shows that these beliefs remained very positive, except for Jan. He stated to have become a bit puzzled about future expectations, since he realised that not all the risks of modern biotechnology are clear, not even to scientists.

> *"After the module, there were questions about cloning and risks and all. First, I did not have any problems with that at all, but now, I'm not really sure. I think that they (scientists) themselves do not even know exactly what to expect. I think there are still a lot of uncertainties."*

Affection

The overall feelings of the confident supporters towards modern biotechnology remained very positive after the science module. Even though the scores in Table 3 show some

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[4] The results of previous research showed that 63% of post-test 'confident supporters' already belonged to the confident cluster at the start of the module. Furthermore, 21.4% were initially students within the 'not sure' cluster. A very small number of the eventual confident supporters was derived from 'concerned sceptics' (5.3%) and none from the 'not for me' students.

Table 3. Differences of the standardized test scores between pre and post-test on attitude factors (questionnaire)

	Cluster		*Cognitive factors (change after post-test)*			*Affective factors*			*Behavioural factors*			*Ethical considerations*		
	cluster pre	**cluster post**	**bio&gen (z-score)**	**biotech (z-score)**	**beliefs (z-score)**	**basic emotion (z-score)**	**unavoid. (z-score)**	**worries (z-score)**	**own intent. (z-score)**	**medical intent. (z-score)**	**crit. intent. (z-score)**	**medical use (z-score)**	**quality. use (z-score)**	**unnecess. use (z-score)**
Rik	confident	confident	+0.11	+0.06	+0.20	-0.15	-0.77	-0.60	-0.20	-0.75	+0.66	-0.36	-0.18	-0.05
Marijke	confident	confident	+0.12	+0.06	+0.40	+0.08	+0.11	+1.20	-0.40	+0.50	0.00	+0.19	+0.26	-0.25
Jan	confident	confident	-0.09	-0.05	-0.60	-0.24	0.00	-0.60	+0.40	-0.25	-1.00	-0.27	+0.11	+0.74
Jona	confident	confident	+0.22	+0.06	+0.20	-0.31	+0.23	-0.60	+0.60	+0.25	0.00	0.00	-0.12	-0.99
Harold	not sure	not sure	+0.01	+0.06	-0.40	-0.69	+0.67	-0.40	+0.20	-0.25	0.00	-0.27	-0.13	-0.19
Marjon	not sure	not sure	+0.11	+0.12	-0.20	-0.61	+0.77	-0.20	-0.40	0.00	0.00	-0.09	-0.23	+0.17
Sam	not sure	confident	+0.12	+0.12	+0.20	+0.24	-0.55	-0.20	-0.80	-0.50	-0.34	-0.18	+0.18	-0.04
Cees	not sure	not sure	0.00	0.00	+0.20	-0.15	-0.23	+0.20	-0.60	+0.50	-0.34	+0.18	+0.49	-0.59
Remy	sceptical	not sure	+0.12	+0.17	+0.60	+0.08	+0.33	0.00	+0.20	0.00	0.00	-0.37	+0.8	+0.06
Esther	sceptical	not sure	-0.19	+0.06	+0.60	+0.23	-0.11	+1.00	0.00	+0.50	+0.33	-0.18	0.00	-0.78
Renee	sceptical	sceptical	-0.20	0.00	0.00	0.00	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sarah	sceptical	sceptical	0.00	+0.18	+0.60	+0.85	-0.67	-0.60	-0.40	+1.25	+1.66	+0.73	+0.31	+0.20
Frans	not for me	not sure	+0.02	+0.11	-0.20	-0.15	+0.33	0.00	+0.40	0.00	0.00	-0.18	-0.03	-0.25
Maria	not for me	not sure	+ 0.02	+ 0.06	- 0.40	- 0.53	+0.44	-2.00	+0.60	+0.75	0.00	+0.55	+1.15	-0.02
Sabrina	not for me	not sure	- 0.30	+ 0.06	- 0.20	- 0.16	0.00	-0.20	-0.40	+0.50	0.00	+0.46	-0.24	-0.32
Karin	not for me	not sure	- 0.19	+ 0.17	+ 0.40	+ 0.23	+0.44	-0.80	-0.20	0.00	+0.34	+0.09	-0.42	-0.35

decline in affection and some gain in worries (Marijke), none of these four students expressed more concerned feelings towards biotechnology.

Behavioural intentions and ethical considerations
In the interviews, besides the elements of intentions of consuming GM foods or genetic-medical intentions, the students were specifically questioned about their intentions and ideas about predictive genetic testing, since this is a so-called ethical and social dilemma within cancer research in the field of genomics and the science module.

Although all four students were in favour of genetic research (behavioural intention in the medical area and ethical perceptions on medical applications in Table 3), they had difficulty deciding whether they should test themselves. However, after the module, two students would conduct a predictive genetic test. The two others were not against it but doubted if the benefits would outweigh the negative (ethical) effects.

In short, all of the confident supporters remained positive, meaning they kept their high levels of understanding and optimistic beliefs, their high levels of trust and positive ideas about future possibilities. Two students stated to have become even more positive and sure about their cluster membership (Marijke and Jona).One student stated to have become slightly more critical after the module (Jan) but this did not result in a shift towards another cluster.

For this type of secondary school student, science education aimed at the development of a solid knowledge base is not the major goal. It might, however, be necessary for the development of a more considered and critical attitude. During the module, their positive views on biotechnology were mainly confirmed. These students gained little insight into the challenging ethical and moral decisions that have to be made about new technologies, taking all risks and benefits into account.

3.2. Not sure

The group of students, identified as being unsure about what to think, feel or do with modern biotechnology is of particular interest, as it represents the largest and less scientifically literate group of students (Klop & Severiens, 2007). Data from the previous study showed that almost half of the 'not sure' students were still 'not sure' after the science module. Furthermore, a considerable number of confident supporters and concerned sceptics made a transition towards the not sure cluster.[5]

[5] Of the total number of students in the experimental groups 37.1% ended up in the 'not sure' cluster. Most of the students already belonged to this cluster (41.1%) beforehand but a considerable number also came from the 'concerned sceptics' cluster (26.8%). Another part of the final 'not sure' attitude cluster consisted of students who initially belonged to the 'confident supporter' (21.4%) and 'not for me' groups (10.7%) (Klop, Severiens, & ten Dam, submitted).

The question is what effect did the science module have on the attitudes of these particular students? In this study, one student turned from 'not sure' towards 'confident supporter' (Sam). The other three students remained 'not sure'.

This mixed group of students appreciated the science module up to a certain level. Sam had no negative remarks about the module, except for missing some explanation on the risks and negative sides of biotechnology. He really liked the visualisation of abstract biological terms (see his remark in the 'implementation' section). The other three students were also in favour of hands-on education, although they claimed to have lost some of their interest and concentration at the end of the module.

Cognition

Although Sam did not think his attitude had changed much, he indicated that the whole experience had made him think. Sam was the only student from the initial 'not sure group' claiming to know more about the subject of genomics after the module than before and to have changed his beliefs about the future. His expectations were more positive after the module although he was not sure that scientists could live up to those expectations (see Table 4).

Sam: "*I know more about, well, how it works, how they do it, research and stuff. But I'm not really sure about the negative sides. That point is still not clear for me, they (the university students) have not told me anything about that.*"

The other three students expressed some doubt on whether the science module had taught them anything about modern biotechnology. Still, because all students scored considerably better on the knowledge test (see Table 3), one can conclude that all students have a more solid knowledge base on the subject of modern biotechnology. Although one student explained this increase on the knowledge test in terms of luck, rather than skill.

Marjon: "*No, I do not know any more than before. I even have more uncertainties than before. Well, I do not know less, you cannot know less, but no, not more. Maybe I did learn something unconsciously, but I think I took a better guess this time, ha ha.*"

Affection

Sam was the only student with a positive change in basic emotions (see Table 3). As he put it:

"*Yes, I'm very positive about it. Especially about medical applications and genetically modified food. I am very happy about that. I think it's a good development for humanity.*"

This in contrast with Cees, who was still not sure after the module, stating:

"Yes, I knew before (the module), I was not sure what to think about, you know, food and stuff like that. I think that is still the same. Food and medicines, I think that's okay. I still feel so so about it, though. But, when it comes closer, like experimenting with people, I still find that dangerous and threatening."

Cees was the student with the least affective changes (see Table 3).

Half of the students saw more need for modern biotechnology after the module, except for Cees and Sam. Cees was somewhat disappointed about what genetic research entails and scored lower on all affection factors (also meaning more worries).

Cees: *"This research, it was quite disappointing, I thought it was quite boring and useless…"*

The decline seen by Sam can also be explained by his doubts about the negative sides of modern biotechnology, which he stated: '*remained quite unclear*.'

All students, except for Cees, showed a slight decline in worries towards biotechnology after the module (see Table 3).

Behavioural intentions

A striking similarity between the three post 'not sure' students is that they did not feel the need to gain more knowledge on the subject, nor the need to consider the possible consequences of biotechnology in the (near) future. The reason, they claimed, was that they did not have to deal with any decisions relating to modern biotechnology at present (see quotations in Table 4).

Harold: "Y*ou know, the problem is, I did not ever have to make a decision about anything in this area, so… well, no real decisions, that is.*"

However, Cees expressed that, if necessary, he would be more capable of grounding his opinions or making a decision. This can be interpreted as gaining in awareness of how to behave or act when confronted with modern biotechnology, a requirement for becoming more scientifically literate.

In conclusion, although three out of four students said that their ideas, knowledge and ways of thinking had not changed, some changes were detected in the scores on each of the factors. First, the knowledge test showed a clear increase for all of these students. Apparently, the module succeeded in creating a more solid knowledge base for these students. The reason why this increase did not result in a more literate cluster seems to lie in the fact that these students consider modern biotechnology as irrelevant to their present-day lives. Apparently, the module did not succeed in explaining otherwise.

Table 4. Characteristic cluster quotations of the 16 students in the post- module interview categorised in to attitude components.

Attitude components	**Confident supporters**	**Not sures**	**Concerned sceptics**	**Not for me's**
Cluster membership	Yes, I am even more positive. I already was pretty positive about it, like it can only get better with those technologies and I still think like that. (Marijke)	It's more that I know, for me it is now clearer what I do and do not approve of. So now I doubt which one is dominant. I think that, in general I'm more pro than against biotech. But I just keep an eye on both sides. (Marjon).	Well, I did change a bit. I think I do approve of more things now, I'm not sure though. Maybe because we talked about it, and I gave it some thought. (Esther*)	Well, I'm not going to investigate it myself, so for me it's not really important. Yes, well that little I do know about it is, but I do not need to know more to decide if I'm going to eat it or not (GM food). (Maria*)
Cognitive component	I do know more about the content, what is meant with it. That I didn't know before (the module)(Rik)	No, I do not know more than before. I even have more uncertainties that last time. Well, I do not know less, you cannot know less, but no, absolutely not more! (Marjon).	Well it is kind of strange; all of a sudden we're discussing biotech in other classes as well. You keep running into it. And then I thought, well that's funny, everybody is talking about it. So you do get a lot of information about it, and yeah, I do think I'm more certain about my opinion. (Sarah)	Yes, I do know more about it. Just because you learned about it, a lot has been explained. (Karin*)
Beliefs	After the module, there were questions about cloning and risks and all. First, I did not have any problems with that, but now, I'm not really sure. I think that they (scientists) themselves do not even know exactly what to expect. I think that there are still a lot of uncertainties. (Jan)	I am more positive about it. I hold high expectations about it. If they can bring it out, well that's another point, but I do hope so. (Sam*)		Well, I'm not really scared of it or something. At least, I'm not scared it will go wrong in the future. I think if it is handled the right way, it will turn out okay. (Sabrina*)
Affective component	No, I do not think cloning is really necessary. It might be handy, but not really necessary. (Jan).	No, it's more because of my religion. With cloning, you're making life out of one person. I think it should take two to make life. (Cees)	It is fine the way it is, why chance it? I'm not sure if it is wrong, but you know, it's fine the way it is now. (Sarah)	Well, I do have the feeling that they're already pretty far ahead with that technology. I think it will turn out all right though, I mean, more than I thought before the lessons. (Frans)

Attitude components	Confident supporters	Not sures	Concerned sceptics	Not for me's
Behavioural intentions	All that environmentally friendly food does not seem to be all that correct after all. The fact that we're eating genes everyday, well that was the last point that won me over. Now I'm not even against that anymore (GM foods). (Jona).	I'm not sure if there is something scary about it, I don't think I'll get sick when I eat it. It doesn't look dangerous in practice. They're not injecting it with something poisonous or something. Or do they? (Sam*) Well, the problem is that I didn't have to make any decisions about this yet, so... At least, not real decisions. (Harold)	Yes, I would have it examined. Especially if my mother turned out to have it. (…). Well, maybe not now, but within a few years, I would like to have it checked, you know, if I have that specific gene. (Remy*)	I do have other intentions than I did before. I did not know a lot about it (...) and now I think as long as it is used for good causes then it's okay to use it. (Sabrina*)
Ethical limits	I think you have to start with solving the big disorders or diseases, and then the smaller ones. That ethical line will form itself. (Jan)	Milk is, you know, with starch, that's so small. With milk, if you genetically alter milk, well, then that's big, it's wrapped in a cow. (Marjon)	Well, they can do research, but then I think, I mean, it's about humans… then you should do research on humans as well, not on animals! (Renee)	Well, I mean if it is at least a bit useful, then I don't mind. But if they're going to make coloured fish with it and all, well that's pretty useless. (Maria*)

Another reason for not changing cluster related to the difference between an ambivalent view and an indistinct view, as we have argued in the previous paper (Klop et al., submitted). The unexpected increase in numbers of unsure students, as observed in the previous study, may be explained by an increase in numbers of students becoming ambivalent in how they feel about genomics. Although two students (Cees and Harold) remained "not sure what to think, feel or do with modern biotechnology", Marjon, seemed to be more explicit about why and how she felt and thought about modern biotechnology. This implies that the meaning of 'being not sure' divided into two different directions after the module; still not sure what to think of modern biotechnology and a more ambivalent and/or questioning point of view.

This explanation is reconsidered in the group of students from the remaining clusters that moved to the 'not sure' group.

3.3. Concerned sceptics

Like the group of the confident supporters, the concerned sceptics were identified as a more scientifically literate group. Within this group, two students kept their cluster membership (Renee and Sarah) and the two others changed into 'not sures' (Esther and Remy). This is in accordance with the results based on quantitative measures in the previous study[6] (Klop, Severiens & ten Dam, submitted). Does this mean that two of the students became less scientifically literate?

The students appreciated the socio-scientific issue of the module, which was relevant to their own lives. The students were very involved and concentrated during the science module, except for Renee. As a strict vegetarian, she could not cope with the idea of animal testing, which was quite apparent during the lab sessions and she left the classroom because of this.

Cognition

Three of the four students within this cluster either maintained their level of knowledge or even gained somewhat (see Table 3). Esther indeed expected to have changed but not towards an indifferent or disinterested point of view:

Esther: "*I think I did change a bit, yes. I think I agree on more things now. I don't know, I guess because we talked about it and I really thought it over.*"

This group of students found it important to have at least a basic level of understanding of fundamental biological and genetic concepts. All of the students (except for Renee, who did not participate in the practical part of the module for personal reasons) gave biotech some more thought after the whole experience. Sarah (still sceptical) declared to have gained more knowledge and had therefore become more sure of her (concerned and sceptical) opinion and she thought it was very important and positive to know more about the subjects involved. The two students, now in the 'not sure' group, claimed to have a more positive point of view after they thought it through, which is also visible in Table 3.

Affection

Remy thought she had a more positive affective reaction, especially when it came to helping people but she still expressed some concern about it:

"*Well, they can help people with it, sure. But still, I still find it very frightening.*"

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[6] Of the 'sceptics' 63.2% stayed put; 5.3% were 'confident supporters' and the remaining 31.6 % was made up out of initially 'not sure' students (Klop, Severiens & ten Dam, submitted).

All but one (Sarah) showed high levels of concern before and after the module (Table 3), with concerned basic emotions and a low feeling for the necessity for modern biotechnology. Sarah clearly pointed some questions regarding the necessity of biotechnology after the module.

Sarah: *"It is fine the way it is now, why changing it? I'm not sure if it is wrong, but you know, it is fine the way it is now."*

Behavioural intentions and ethical perceptions

Most of the students were more positive about their intentions towards biotechnology (see Table 3). As Remy said:

> *"Well, I didn't realise it (modern biotechnology) was already this nearby. Now I realise I am already eating GM foods! I didn't get sick so far, so I guess it's probably okay."*

Remy also changed her mind on predictive genetics in a more positive direction, just like Renee and Esther (Table 3).

Most remarkable about the students of this cluster was that they all indicated to have actually reflected on the biotechnological subjects, during and after the module, in class and at home. Although two students changed cluster, in the interviews after the module, they all still expressed some level of concern and scepticism.

In sum, the students within this 'sceptics cluster' could indeed be called scientifically literate, since they know of and thought about the effects and consequences of modern biotechnology in their personal lives.

The difference between the students who did and did not shift is the fact that those who shifted developed a somewhat more moderate point of view towards emotions and intentions towards biotechnology. They became somewhat less sceptical about some biotechnological applications and remained critical and/or concerned about some of the other issues. It is likely that the interpretation we presented for the division of 'not sures' after the science module can be given here as well: the students moving from a critical stance to the 'not sure' group have become more ambivalent in their points of view. In that sense, a shift from a 'sceptical' attitude to a 'not sure' attitude does not imply a decline in scientific literacy.

3.4. Not for me

Teaching about modern biotechnology and especially for the promotion of scientific literacy, is the hardest but most needed for this kind of student; the 'not for me's'. These students stated beforehand not to be interested in science, not to mention modern biotechnology. They did not see any reason to become involved. However, the educational features within this module seemed to have been most appealing to this group. They all gained knowledge, had a more considered affective reaction and perhaps most importantly, realised that modern biotechnology is already part of everyday life.

All students in the 'not for me' cluster made the transition to the 'not sure' group. The students gave the following explanations for this remarkable outcome.

First of all, Maria said she might have appeared more negative the first time than she actually was. Frans stated to have become more neutral:

> *"It's not that I don't care, but in some cases I think it's no problem, and with other issues it is. So you have to be a bit neutral about it.*"

Sabrina said:

> *"Well, I think my point of view did change a bit. At least, with the second questionnaire, so to speak, I filled in different things. More like, you know, it's okay with me…*"

All four students think they have become a bit more positive, although none of them could really explain why.

Cognition

Maria and Frans both agreed with the fact that some knowledge of the subject matter is important and there was indeed a clear shift in the cognitive factors (Table 3). Three out of four had a higher score in the post-test. Sabrina scored slightly lower but she already scored notably higher on the pre-test. Even though their own perception was that they still did not know very much, they reckoned to have learned something from the module.

Sabrina: "*Well, I still do not know much about it, but at least more than last time, I guess.*"'

Maria: "*I don't know exactly what question it was, but when I filled out the list* (questionnaire) *I thought, hey, I've learned about that during class* (module)."

Affection

On the affective component, they all became less reserved or less worried about biotech, which is also apparent in Table 3:

Karin: "*I know now how they handle stuff, you know, they are very careful with what they're doing* (refers to assisting students). *It is much safer than I had expected. With those machines, you know, they are really careful and they wear gloves and all.*"

On the other hand, as Frans stated: "*Yes, I think a have more faith in it. I don't know why, but I gave it another thought and yes, it might work out well. Well, maybe not always…*"

Another notable effect was that all the students displayed more awareness of the fact that biotechnology becoming more and more part of everyday life is inevitable (unavoidable factor, see Table 3).

Behavioural intentions

There is no clear shift in the behavioural intentions of this group. Two out of four students become more positive about genetic testing. Two out of four students will more often eat GM foods; the two other seem to have decided to eat GM foods less often (Table 3). None of the students gave a really well considered argument, for example:

Maria: *"If someone would say, here you have something nice to eat and it's a genetic thingy, I would still eat it. I mean, if it's already there, why not?"*

Or

Frans: "*I don't know what is already genetically modified or not, so I would probably eat it. I'm not going to check the labels in the supermarket.*"

In conclusion, all of the 'not for me' students shifted to 'not sure' students. They seem to have become less reluctant and a bit more aware of "modern biotechnology already being around". Although the students indicated to have learned something about biotech and they became a bit less worried about modern biotechnology, they were still not able to make up their minds completely. The main reason for the shift seemed to be a realisation of "it is already happening around us". The results of the cognitive component (Table 3), and the indication of awareness of modern biotechnology in our everyday lives, might imply a small step towards a more scientifically literate attitude.

4. Conclusions and discussion

The aim of this qualitative study was to explain changes in attitudes towards genomics after an innovative science module. The science module was developed to promote or stimulate students' awareness and communication of social and ethical issues associated with modern biotechnology. We have investigated if and why students change their views on modern biotechnology in the course of this science module. How did the students interpret and explain the changes in their attitudes and did the combination of the different instructional features stimulate students to develop their attitudes towards modern biotechnology?

We found that the science module resulted in an increase in more attitudes that are positive and in more ambivalent or questioning attitudes. This is partially in line with other research on attitudes towards biotechnology. Several studies on attitudes towards biotechnology found that those who gained a better understanding of biotechnology (whether or not because of an educational course) held an overall more positive attitude afterwards (on genetic engineering Chen & Raffan, 1999; Lock, Miles, & Hughes, 1995) or a more critical attitude (Gaskell, Allum, Stares, & et al., 2003). However, others found no or neutral effects of science modules (Bredahl, 2001; Dawson & Soames, 2006). To what extent these studies are comparable is, however, questionable; attitudes towards biotechnology do not yet constitute a coherent research area. Some studies defined attitudes in terms of benefits and risks, some in terms of acceptability and others in terms of a general evaluation (for review see Klop & Severiens, 2007).

As far as a well-considered affective reaction is concerned, the confrontation with this science module made the more concerned or negative students doubt their scepticism. This outcome might indicate that most students gave biotechnology further thought; "what does it mean to me?" Several students indicated that only after the science module, did they realise that modern biotechnology is already part of their (everyday) lives; as they are most likely already eating GM foods. In addition, the majority of the students showed less worries about modern biotechnology after the module, most likely also because of this realisation. Most students claimed to be more certain of what to do when confronted with modern biotechnology or at least, to be more 'equipped' to make decisions when necessary. In terms of scientific literacy, it was expected and in previous research using quantitative measures established (Klop, Severiens, & ten Dam, submitted), that the science module as described in the present study would stimulate the development of scientific literacy on modern biotechnology.

However, all these changes and realisations due to the science module resulted in a large group of students who were not (no longer) sure what to think of modern biotechnology. Does this mean that the science module is an ineffective means of achieving more scientifically literate students in this particular group? After all, we labelled these 'not sure' students as less scientifically literate. Based on the participants' responses, one can argue that this is not the case. Students claimed to have gained more understanding and awareness of biotechnology. This was also observed in the results of their post-attitude tests. The fact that this does not always translate into a shift towards a more literate attitude cluster can be explained in two ways.

The first one concerns the perceived irrelevance to students' present-day lives. The students that gained knowledge but remained unsure stated that they saw no relevance in reflecting on genomics. They gained more understanding of the subjects but they did not see any advantage in truly considering the pros and cons of modern biotechnology. Apparently, the module did not succeed in explaining otherwise. Implementing the reflection activities to a larger extent may help these students to realise its importance in their own lives and may result in a move towards the confident cluster or to the concerned sceptics cluster. This lack of relevance for students has also been confirmed as a key problem in (science) education in other research (Millar and Osborne, 1998; Gilbert, 2006, National Research Council, 1996).

A second reason for the increase in the 'not sure' group, relates to the difference between ambivalent and indistinct views. The unexpected increase in numbers of unsure students observed in both studies can be explained by an increase in the numbers of students becoming ambivalent in how they feel about genomics. Although the 'not sure' students were not capable of choosing sides, they showed a considerable development in understanding of relevant biological and genetically concepts and had more outspoken feelings (although ambivalent) and awareness of issues associated with modern biotechnology. In the case of the 'pre-sceptics', they seemed to have moved from a critical certainty about what they believed they understood about biotechnology, to more reflective awareness of the complexity of modern biotechnology. This made them more doubtful, since they had not been confronted with these sides of biotechnology before.

It is likely that if the module had put more emphasis on the ethical and social side of modern biotechnology (since they are concerned about it) and the positive as well as negative side effects (technical or social), to a greater extent perhaps, this group would hold more pronounced attitudes (more critical or more positive).

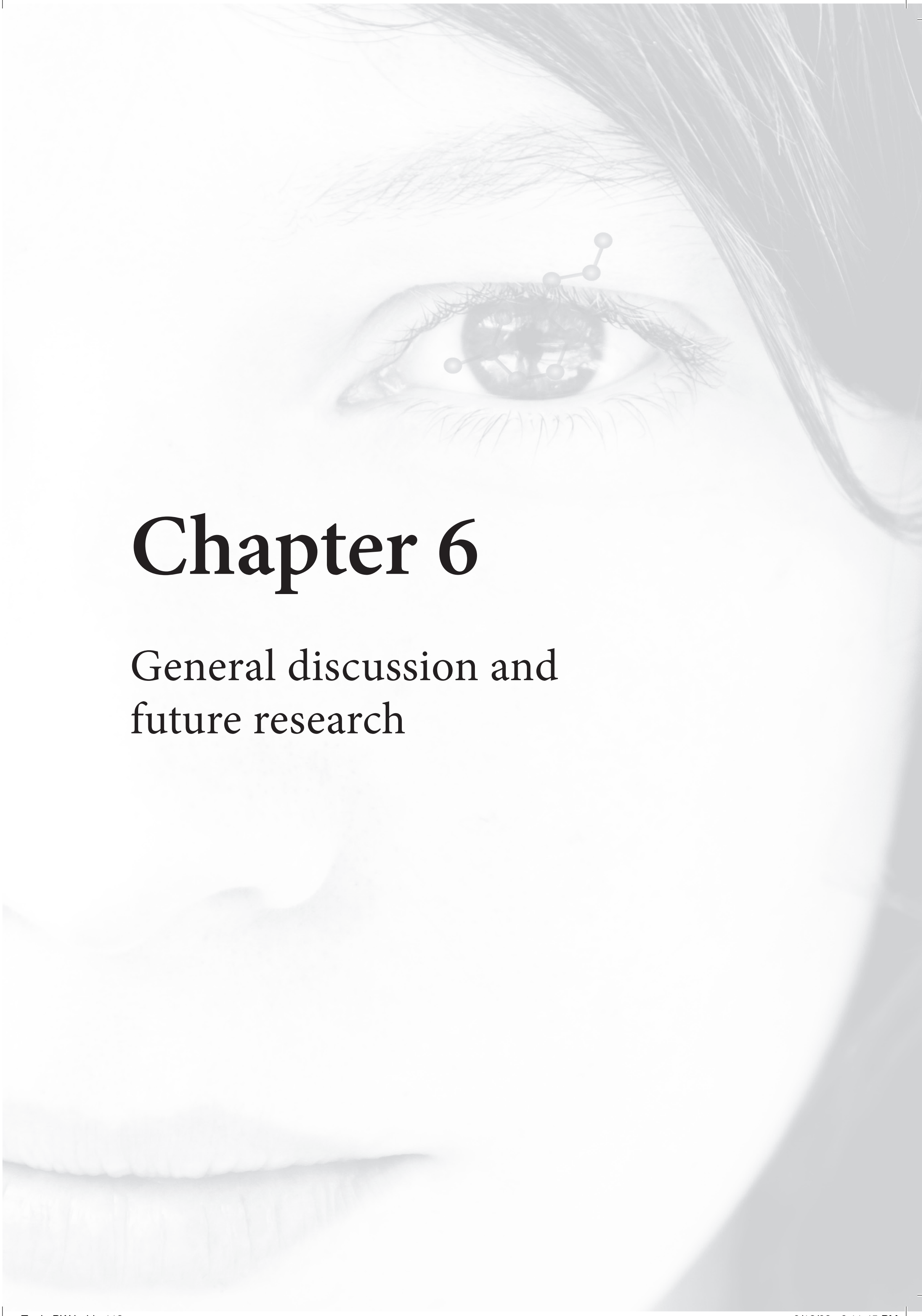
The most stable group, the confident believers especially, gained in understanding and awareness. Sam, the only student who made a transition from not sure towards confident, learned a lot from the science module, showing a more defined attitude afterwards and stating the whole experience had made him think, especially about ethical issues. He claimed to have more knowledge, feelings that were more coherent and a positive belief. He also claimed to still wonder about the negative sides of biotechnology, as they were underexposed within the module. One can conclude that for a transition towards a well-defined and well-founded attitude, gaining understanding and awareness is not enough. One also has to be triggered on affection and intentions and activated to reflect upon the subject and on oneself.

The present study has shown that the combination of the learning activities in the science module has resulted in an increase in knowledge and more pronounced attitudes towards genomics. Given the design of our study, it is not possible to disentangle the effects of each of the learning activities. Was it the group work that invited students to rethink their points of view? Was it the hands-on experience? Will an increase in reflection activities indeed foster scientific literacy among students to a greater extent? In the future, a new experimental study should be set up. Investigating the process of attitude change before, during, and after a science module, including conditions that vary in these types of learning activities, could provide a closer look into the effects of particular design principles and learning activities.

4.1. Implications for science education

Science modules such as "Read the language of the tumour" can be of great value in the promotion of scientific literacy for all students. Even the least interested and somewhat problematical group, the 'not for me's' (Klop & Severiens, in press), appreciated the module and showed some development towards a more scientifically literate attitude. However, and as stated previously, no development towards more sceptical or considerate attitudes was established.

Within the science module, students were confronted only to a limited extent with the possible risks or ethical dilemmas involved in biotechnology. They were hardly invited to think critically about their newly acquired knowledge and feelings and the discussions they had with their peers on the subject. These are, however, important factors in developing scientific literacy (Sadler & Zeidler, 2004; Zeidler, Sadler, Simmons & Howes, 2005; Zeidler, Walker, Ackett & Simmons, 2002). In our opinion, these types of science modules should not be supervised only by biology or science students. Involvement of more ethical or critical points of view, like spokespersons for conservation groups (Greenpeace), could be of great value. Therefore, we would like to argue that in the interests of fostering informed and critical citizens; science education should focus on all aspects of genomics, the advantages, as well as the disadvantages, the technical as well as the ethical.



Chapter 6

General discussion and future research

Genomics and its associated technologies (or modern biotechnology) have a major impact on society, and the impact is growing. It will ultimately alter our health care, industry and agriculture, and maybe even the length and quality of life itself (e.g. Gaskell, Allum, Stares, & et.al., 2003; Heijs, Midden, & Drabbe, 1993; Kirkpatrick, Orvis, & Pittendrigh, 2002; Macer, 1992; Pardo, Midden, & Miller, 2002; Waarlo, Brom, Nieuwendijk, Meijman, & Visak, 2002). Because of these developments, it is important that the public understands the main concepts behind modern biotechnology. Young people of today will need such knowledge in their future careers and in their daily lives as members of a fast changing society, in order to make well-informed decisions about issues related to science and technology. For this reason, it has been recognised that a major goal of school science education should be the promotion of scientific literacy in this field. However, there is still considerable indistinctness about the meaning of scientific literacy and the implications it should have for the science curriculum (DeBoer, 2000; Hodson, 2002; Jenkins, 1990; Kolstø, 2001; Laugksch, 2000). Consequently, there are varying interpretations of how and what kind of abilities should be incorporated into school science curricula; what is important for students to know, value, and be able to do in situations involving science and technology? Current thinking about the desired outcomes of science education emphasises scientific knowledge and an appreciation of science's contribution to society (Hazen & Trefil, 1991; Jenkins, 1992; Millar & Osborne, 1998; OECD, 2006; Thomas & Durant, 1987). Within this thesis we have argued that the aspiration of science education should be to enhance those competences that students need to be able to live, and participate with reasonable comfort, confidence, and responsibility in a society that is deeply influenced and shaped by the applications, ideas and values of science (in accordance with Millar, 2006). This generally implies the development of cognitive, affective, and behavioural abilities needed to function effectively in a technology dependent society (Bingle & Gaskell, 1994; Dimopoulos & Koulaidis, 2003; Jenkins, 1992, 1997; Miller, 1998). Translated to the goals of science education, this means stimulating students to base their attitudes towards modern biotechnology upon a solid cognitive foundation, a detailed and contextualised affective association, and with that, knowing what to do or how to behave when confronted with it. This particular combination of "thinking, feeling, and acting" bears similarity to the attitude model as described in the tripartite theory of attitude (Breckler, 1984; Chin, 2005; Eagly & Chaiken, 1993; Katz & Stotland, 1959; Rosenberg & Hovland, 1960).

In this thesis, we have examined in detail the attitudes of secondary school students towards modern biotechnology, and the effects of a science module on the different attitudinal components, using the theoretical framework of the tripartite attitude theory. In this last chapter, the issues that resulted from the studies that were carried out are further discussed. Following from this, some of the questions that can be raised after considering the results will be posed, and the related possibilities for future research will be addressed.

1. Discussion

The central focus of this thesis is on secondary school students' attitudes towards modern biotechnology. An instrument (questionnaire) was developed to measure and categorise students' attitudes in specific attitude-clusters (chapter 2). Relationships between the attitude-clusters and students' background and value factors were examined (chapter 3). The effects of an innovative science module on the development of scientific literacy, expressed in attitudinal changes, were studied in a quasi-experimental and a qualitative study (chapter 4 and 5).

The following section will interpret the main results of the studies in accordance with the related research questions. We will submit these findings to a closer examination, since the studies in this thesis have also resulted in questions about the models we used and the science education-area more generally.

1.1. Exploring attitudes towards modern biotechnology

The first issue in this thesis concerns the lack of knowledge about what young people actually know about modern biotechnology, and what their views and opinions towards its applications are. Many surveys on attitudes towards modern biotechnology or science employ one-dimensional measures (Pardo & Calvo, 2004; Pardo et al., 2002), thereby ignoring the rich literature in (methodological) attitude research as well as the complex nature of the attitude-object (Pardo & Calvo, 2002). Attitudes towards biotechnology are often measured, for example, by the question 'how do you feel about certain biotechnology issues' (negative or positive). Such one-dimensional measures do not provide a rich basis for developing effective science education, aiming to stimulate students to develop scientific literacy abilities. Therefore, a necessary first step in developing science education is to examine the current attitudes of students and take into account possible differences according to, among other things gender, educational and cultural background.

The first study, as reported in chapter 2 and 3, explored secondary school students' views on genomics in more detail compared to previous research. The problem statement of the first part of the thesis is; what are the attitudes of secondary school students towards modern biotechnology? In order to be able to answer this more general question we formulated three research questions.

1 *What kind of cognitive and affective evaluations and behavioural intentions can be observed? In addition, how do these attitude-components interrelate?*
2 *Can different attitude-patterns among secondary school students be distinguished?*

3 What are the relationships between background factors, the underlying values, and different kinds of attitudes towards biotechnology?

The tripartite attitude theory provided a solid model that reflected our view regarding the complexity of attitude towards genomics. In this theory, attitude is assumed to consist of a cognitive, an affective and behavioural component. This theory was our starting point for the exploration of attitudes towards genomics in more detail.

To answer the first research question: Which cognitive, affective evaluations and behavioural intentions can be observed? A questionnaire was developed within the framework of a multi-component concept of attitude, consisting of various cognitive, affective, and behavioural features. The development of the instrument was based on a pilot study (interviews) with the target group (16 year old secondary school students) and researchers in the field of genomics, and several existing questionnaires, among which is the Eurobarometer. The questionnaire consisted of questions and statements representing various aspects of modern biotechnology.

On the basis of exploratory factor analyses of the results of the questionnaire (n = 574), nine attitude factors underlying the three basic attitudinal components could be distinguished. In Table 1, the observed components and factors are described.

Table 1. Attitude components and underlying factors with description

Attitude components	Attitude factors	Description
Cognitive component	Biology and genetics	Knowledge of biology and genetics
	Modern biotechnology	Knowledge of modern biotechnology and its applications
	Beliefs about modern biotechnology	Evaluative knowledge of biotech or beliefs about biotechnology
Affective component	Basic emotion	Basic emotional reactions, such as being scared or excited
	Unavoidable	Feelings of biotech being unavoidable; 'it is going to happen anyway'
	Worries	Worries about biotech, i.e. feeling of unease regarding biotech developments
Behavioural component	Own intentions	Intentions to consume when there is a personal gain; for instance when genetically modified (GM) products are cheaper or contain less fat
	Medical intentions	Medical intentions such as undergoing genetic tests
	Critical intentions	Intentions to consume when critical conditions are met; e.g. environmentally friendlier

The results reported in chapter 2 indicated that the developed questionnaire was able to measure students' attitudes towards modern biotechnology in a reliable way. It demonstrated that attitudes are a multi-dimensional construction, thereby clarifying that attitudes should not be measured by one or two 'attitude questions'. However, in several (large and international) surveys little to no attention is paid to content of attitudinal items which lead to metrical and conceptual weakness of scales and by that empirical support for some published results is very limited (in accordance with Miller, 2001; Pardo & Calvo, 2004).

The results of the questionnaire lead to the following research question:

Can different attitude patterns among secondary school students be distinguished?

This question was answered by performing a K-means cluster analyses on the nine attitude factors above-mentioned. The attitude factors interacted with one and other in different ways, resulting in a specific set of four general attitude patterns among the students (clusters); '*confident supporters*', '*concerned sceptics*', '*not sure's*' and '*not for me's*'.

The 'confident-supporters' were a positive, pro-biotechnology, and well-informed group of students, who seemed to welcome biotechnology in their daily lives. The 'concerned sceptics' also formed a good informed group of students, only they demonstrated a sceptical, concerned, and questioning stance towards claims made about modern biotechnology. The so-called 'not sure's' formed the largest group. These students' views tended to be rather unclear; they were neither anti- nor pro-biotechnology and their overall understanding of the subjects left room for improvement. The smallest group, the 'not for me' students, was very negative and ignorant about biotechnology. Their beliefs and affective reactions were very negative, and based on poor knowledge and understanding of the subjects.

The findings in this study confirmed partially what is frequently assumed and emphasised in studies on attitudes towards biotechnology or science in general, namely the more one knows about the subject, the more positive one's feelings and the more positive the behavioural intentions are (European Commission, 2006; Hill et al., 1999; Pardo et al., 2002). However, and in contrast to these studies, the quantitative study as described in chapter 2 also showed that among a large group of students ('not sure' and 'concerned sceptics') a different pattern of relationships among the three attitude components emerged. In these two groups, a somewhat reasonable to good cognitive basis combined with neutral or even negative affective responses and behavioural intentions. These results clarified and thus emphasised, that with respect to a complex subject such as modern biotechnology, each of the attitude factors that comprise an attitude has its unique contribution to the overall attitude. To state one has a bad or good attitude does not do justice to the overall discussion about attitudes towards modern biotechnology. The complexity of the object itself however, in terms of for example medical applications or food issues, has not resulted in separate attitude factors, or separate attitudes. It seems that the fact that we are dealing with modern biotechnology is the relevant issue, and not so much whether it concerns medical issues or food issues.

To further explore attitudes towards genomics, relationships with the attitude-clusters and the students' background and several value factors were examined. Clearly, a multitude of variables could potentially influence the attitudes students have. These relationships can provide indications of the interplay between attitudes on the one hand, and related values and opinions about biotechnology on the other hand. It also clarifies whether certain groups are overrepresented in a certain attitude clusters. This insight is needed as input for potentially successful science education reckoning with differences among students. Therefore, the third research question reads as follows**:**

What are the relationships between background factors, the underlying values, and different kinds of attitudes towards biotechnology?

The results are described in chapter 3.

The examined background factors of the students were gender, religious and ethnic background, personal experience, level of education and achievement. Much research has been done on these background factors associated with attitudes, especially towards science in general and science education. However, most research focuses on one specific background factor. We wanted to find the relation between the background factors of students and the different attitudes. Therefore, the first step in the analysis was to determine the association between a set of relevant background factors and the different attitude clusters. The results of the second study confirmed former results on gender differences: boys more often seemed confident supporters of biotechnology, whereas girls more often were concerned sceptics or not sure what to think of it (Neathery, 1997; Schibeci & Riley, 1986). The same could be said for the educational levels; students within the higher levels of education were more likely to be confident supporters. The level of education seemed to be a stronger predictor than religious and ethnic background.

In the second step, all value factors (ethical considerations, benefit perception, interest) were included in the analysis as well. Results showed there was a significant relationship between educational level, ethical considerations about medical-, qualitative - and 'unnecessary' applications of biotechnology and perceptions of benefit on the one hand, and attitude towards modern biotechnology on the other hand.

The second analyses indicated that the differences between boys and girls could not be explained by the difference in interest in science, as often is seen in gender studies, but by a different way of considering ethical matters of biotechnology. One can explain this by the fact that several biotechnological applications and research will and can affect girls differently than boys. After all women are the suppliers of egg cells and embryos needed for stem cell-research. They are the ones that play a crucial role in the prevention of congenital abnormalities and stand for the choice to undergo an abortion if a genetic test turns out with bad result (see Huijer & Horstman, 2004).

Besides gender, ethnic background and educational level turned out to be important background factors. Minority groups as well as students in the lower educational (vocational) tracks, were overrepresented in the 'not for me' and the 'not sure' groups. In other words, all groups that on average perform less well in the educational system; girls (in science tracks), minority groups (in academic tracks), and students in the lower educational levels are over represented within the less scientific literate groups.

The ethical points of view of students, as well as their perception of benefits were strongly related to their overall attitudes towards modern biotechnology. It seemed that students, who had problems with the use of biotechnological applications because of their ethical views, had a more overall critical attitude concerning modern biotechnology. The more critical groups also seemed to expect less benefits of modern biotechnology compared to students within the neutral or positive groups.

In sum, the study discussed in chapter 3 showed that students with more developed attitudes (confident supporters or concerned sceptics), were more often boys than girls, stemmed more often from higher educational tracks, held more outspoken ethical views, and more strongly considered the benefits of developments in modern biotechnology, than did students with poorly developed attitudes. The conclusion that must be drawn from these results is that science education should not only focus on what or how technological and science related subjects are taught, but also to whom. Paying attention to ethical views, and inviting students to think about benefits and risks more closely, might help different groups of students to create a more balanced attitude towards biotechnology. This might be especially helpful for girls and students in lower educational and vocational tracks.

The outcomes and conclusions of the first part of this thesis gave rise to the research questions that were investigated in the second empirical study; the effects of science education as a means to develop students' attitudes towards genomics.

1.2. Attitude development in science education

The second part of the thesis is intended to develop a greater understanding of science education aiming to improve scientific literacy among secondary school students.

If we are to understand the impact of science education, the links between students' attitudes and classroom practices are essential to examine.

The main question in this part of the thesis is to what extent science education can bring about attitudes that are more profound, more outspoken. As we have set out in the first chapter, attitude is a 'descriptive concept', whereas scientific literacy is a 'normative concept'; one needs a certain level of scientific literacy in order to function effectively as a citizen and consumer in our technologically driven society. Given its central role in science education, we used the concept of scientific literacy in the second part of the thesis. In our view, scientifically literate people hold confident ('the confident supporters') or sceptical ('the concerned sceptics') attitudes toward modern biotechnology. Given the high percentages of students in the 'not sure' and 'not for me' groups, asks for science modules aiming to raise students' knowledge and awareness of modern biotechnology.

In chapter 4 and 5, the effects of such a module on students' attitudes were investigated. A new Dutch science module for the upper levels of secondary education was used to this end. On the basis of an analysis of the science module, we identified several design principles, inspired by a social constructivist perspective on learning. The module emphasised the integration of *thinking* (cognitive ability), *feeling* (affective ability), and *acting* (associated behaviour). According to this perspective, we argued that this module might help students to create a more balanced attitude towards biotechnology (in accordance with Wood, 2000).

The general issue is whether students become more scientific literate because of this science education module, and what underlying explanations can be given for changes in students' attitude.

The first research questions in the second part of this thesis can be phrased as follows:

What are the effects of a science education module on attitudes of secondary school students towards modern biotechnology?

A quasi-experimental design study was set up, to examine the effects of this science module. Chi-square tests showed that the science module, instructed in the way it was, had a small, but significant effect on attitudes. Almost five percent of the students showed a more scientifically literate attitude at the end of the module, by changing over to the 'confident supporters' or 'concerned sceptics' clusters. These findings were in agreement with previous research on effects of constructivist approaches to teaching (among others, Conner, 2004), which also showed small but positive effects on attitudes towards science. Although the change seemed small, it was brought about in only four lessons. This is relatively quick, especially for attitudinal changes. However, based on the combination of design principles (Conner, 2000) and the socio-scientific and relatively new school-subject matter (Sadler, 2002; Zeidler et al., 2005), we had reason to believe that even a short module could bring about changes in attitudes. Previous research has indicated that direct participation in science activities has a positive impact on the attitudes of children and young adults (George & Kaplan, 1998). This was also confirmed in our study. On the other hand, an increase in 'concerned sceptics' was also hypothesised, but not found. We argued that although some critical points were given on several societal issues concerning biotechnology within the science module, the module emphasises the benefits of cancer research using biotechnology. For that reason, the likelihood of students changing into a 'confident supporter' instead of 'concerned sceptics' was much greater.

Contrary to our expectations, a rather substantial group of the students had moved internally from the 'confident supporter' group and the 'concerned sceptic' group to the 'not sure' group. This unexpected finding could be accounted for either by the used definition of 'not sure' or the attitude-questionnaire itself. We have defined the 'not sure' group as a less scientific literate group of students. This may not be a correct interpretation for at least some of the students in this group. During the science module students obtained new knowledge, they heard about new dilemmas, they discussed these dilemmas with peers, interesting students from university supervised the hands-on work, and so on. In addition, some of the respondents wrote remarks on their questionnaires explaining that picking an answer was 'way too' difficult because they had mixed feelings about certain issues. In hindsight, it may not be strange that some of these students became unsure of what to think. Perhaps being unsure also means a transitional stage towards a new and more detailed or more stable attitude towards modern biotechnology. In other words, some students may be rather ambivalent than strictly unsure or undecided. Gardner (1987) discussed the complicated effect of ambivalence on the validity of science attitude measurement scales, suggesting that simple responses may miss the complexity of the underlying attitudes. The instrument, however, made no (quantitative) distinction between ambivalent responses from undecided responses. As a consequence, no perception of internal attitudinal changes in 'being not sure' could be established. This will be elaborated upon in the section on limitations and future research.

The results described in chapter 4 were further explored and discussed in Chapter 5, thereby answering the following research question:

How do the students interpret and explain the changes in their attitudes?

A qualitative research method was used to investigate the effects of the science module in more detail, using a case study method. Four secondary school science classrooms participated in this case study, of which sixteen students were interviewed on aspects of their attitudes towards modern biotechnology before and after participating in the experimental science module. Pre- and post-attitude questionnaires (chapter 4), classroom observations, and pre- and post-module interviews were used to follow students' attitudinal changes. First, the findings suggested that our interpretation of the attitude-clusters was supported by the students, thereby suggesting construct validity of the four attitude-clusters. Secondly, our aforementioned explanations of attitudes changes were also confirmed. The confrontation with the science module made the more concerned or negative students doubt their ways of looking at modern biotechnology, explaining the transition towards the 'not sure' cluster. Nevertheless, all students claimed to have gained more understanding and awareness of biotechnology, which was also observed in the results on their post-attitude tests.

During field observations, we have seen that there was a discrepancy between the intended, implemented and attained curriculum (van den Akker, 1988) at several important learning activities, of which we believe are needed for developing scientific literacy. This means there was a difference between how the science module was designed and how it was put into practice in class. It became obvious that during the science lessons, students were hardly confronted with the possible risks or ethical dilemmas involved with biotechnology, and thereby not all students were invited to participate critically in the practice. Another problem was that most teachers omitted (most of the) reflection activities (also described by Knippels, Rijst, & Severiens, 2006; Waarlo, 2007). Reflection is viewed as a way to give learners more control over their own learning, and to integrate new knowledge into existing structures. By omitting this activity, a relatively large group of students was not challenged to think critically about their newly acquired knowledge and feelings and the discussions they had had with their peers on the subject. These are, however, important learning activities for developing scientific literacy.

The studies have shown that most students did give biotechnology another thought. Several students indicated that only after the science module, they realised that modern biotechnology is already part of their everyday life, hence the citation: *'I never really thought about it...'* In addition, the majority of the students showed less worries about modern biotechnology after the science module. As far as behavioural intentions are concerned, most students were more certain of what to do when confronted with modern biotechnology or at least be more capable to make decisions when necessary.

Furthermore, it became clear in the final study that all students, from all different attitude-clusters, greatly appreciated the science module. They truly enjoyed the hands-on experience, small group work and all other features of the module. In terms of scientific literacy, the science module as described in chapter 4 and 5 with a combination of particular learning activities has resulted in a small but positive development in scientific literacy of the students, even among the least interested groups of students.

1.3. Conclusions

Based on the findings presented in the studies of this thesis, several conclusions can be put forward.

A first conclusion, based on the results discussed in Chapter 2, is that we were able to develop an adequate instrument to measure secondary school students' attitudes towards modern biotechnology in a reliable way. Furthermore, we argued that attitude towards biotechnology is a concept with a complex underlying structure of different cognitive, affective and behavioural features. These features interact in a certain way, resulting in different kind of attitudes among the students. More specially, it was found that almost half of all students were not sure about their feelings and thought about modern biotechnology. As concluded in Chapter 3, this particular group of students could be identified as somewhat of a 'risk group' within science education. All groups that somehow lag behind in the educational system, girls (in science classes), minority groups and students of the lower educational levels, were overrepresented in the 'not sure and not for me'-groups, characterised as deficiently scientific literate.

Our study also suggests that attitudes towards modern biotechnology are a good approach to describe and measure scientific literary or scientific literate abilities. Promoting scientific literacy is recognised as an important goal of school science education. Within our studies, we have conceptualised becoming scientific literate as broadening and strengthen one's attitude towards modern biotechnology. In this way, we gave the normative concept of scientific literacy a concrete definition and operationalisation. It provided an opportunity to describe levels of scientific literacy among secondary school students and concrete changes in these levels, as presented in Chapter 4.

Another main conclusion, discussed in Chapter 4 and 5 is that when students are offered well thought-out and balanced science education, it does stimulate them to base their attitudes towards modern biotechnology upon a broader cognitive foundation, a more considered affective association, and it enhances the ability to know what to do or act when confronted with it. This is in particular important for the large group of secondary school students that are unsure of their point of view towards modern biotechnology.

By well thought-out and balanced science education we mean that in the science curriculum, the emphasis should not only be on scientific knowledge but also on the societal aspects of science, in particular its contribution to and influence on society and how it will or can be important in daily life.

In the Netherlands, there is a growing interest in reforming science education. In the latest curriculum proposals for biology-education at secondary schools (Boersma et al., 2007; CVBO, 2005) there is more attention for the differences in attitudes towards science between students than before. There is a renewed interest in the development and implementation of context-based science education. Researchers and curriculum developers suggest focusing on concepts and contexts; meaning less emphasis on studying subject matter disciplines for their own sake, and more on learning subject matter disciplines in the *context* of e.g. science in personal and social perspectives. Contexts are meant to explicitly relate sciences and technology topics to socio-scientific issues. This is expected to increase personal relevance for the students and foster scientific knowledge building (Boersma, 2006). The results in the present thesis provide input for this point of view.

1.4. Limitations and future research

All answers found through scientific study raise new questions, and the answers provided in this thesis are no exception. In this section, some of these questions will be addressed and some lines of future research are proposed.

Are the 'not sure's' really not sure what to think?

The studies revealed a large group of students with a somewhat indifferent and uninterested attitude. However, we also found that this particular group is a very heterogeneous group of students. Meaning some students were more ambivalent rather than truly unsure or undecided. In our studies, the questionnaire failed to distinguish between students with truly unsure views, and students that were ambivalent and thus choose sides depending on the context or use of the biotechnological application. This finding seems to ask for the conceptualisation of a fifth attitude, which can also be considered a scientific literate attitude: the '*it depends on the circumstances*' attitude. With this in mind, the questionnaire could be refined, for example by adding an extra option within the Likert-scales, thereby measuring ambivalent responses (Gardner, 1987; O'Muircheartaigh, Krosnick, & Helic, 2000). If such a fifth attitude would indeed emerge, it would improve the construct validity of our questionnaire.

How to measure the perception of risks?

The instrument was not able to establish a reliable scale measuring the perception of risk of modern biotechnology. Pardo et al. (2002) experienced a similar problem; their structural model also failed to predict the perception of risk. It remains unclear, however, why on the other hand the expected benefits could be measured reliably. We argue that benefits of biotechnology refer to one underlying dimension (you either see benefits, or you do not), whereas risks of biotechnology refer to a number of underlying dimensions, thereby resulting in an unreliable scale. Risk perception may not only be a question of cognition, but also of subjective probability, believes or feelings towards risk. Some studies have therefore focused on worries or concerns rather than risk (e.g. MacGregor, 1991). Nevertheless, and other research on attitudes has established this, we consider that risk and benefits-perceptions of modern biotechnology have a considerable impact on attitudes (e.g. Renn & Rohrmann, 2000). Future research should focus more on the possible underlying construction of benefit and especially risk-perceptions. A more qualitative design is suggested to uncover these dimensions.

Are the changes in attitude persistent over time?

In this study, we performed a pre- and post- attitude test to follow students' attitudinal changes after an innovative science module. However, the time in between pre- and post-test was approximately one to one and a half month. A long-term effect study should be designed to evaluate the effects of science modules or programmes designed to improve scientific literacy in the long run. What is the persistence of the effects? What happened with the changes in attitudes in for instance six months time, have the effects vanished or maybe intensified? This will provide not only valuable information about the effectiveness of science education, but also about the durability of attitude changes.

Is the educational level of students really a better predictor than their religion or ethnic background?

The effects on attitudes of religion and ethnic background in relation to the effect of educational level should be measured more closely. As explained in chapter 3, level of education seemed to be a stronger predictor than religious and ethnic background. At the same time, we stressed that the number of students participating in our study from non-native backgrounds and from the different religious groups were relatively small and heterogeneous. We have to be careful therefore with our conclusion that educational level is more important than ethnic or religious background. Our suggestion for future research would be to conduct a qualitative study, including students from each religious and ethnic group, within each educational level. Such a design could provide a more detailed answer to our research question about the effects of religion, ethnic background, and educational level on attitude towards modern biotechnology.

What are the key factors within science education?

The results of this study gave indications about the effectiveness of a science module utilizing a combination of design principles and learning activities. Given the design of this study, it was not possible to disentangle the effects of each of the learning activities (e.g. active learning, inquiry-based learning, use of authentic tasks). A new experimental study including conditions that vary in these types of learning activities could show the effects of particular instructional features and learning activities. The aim of this study should be to determine the best way to effectively make use of combinations of design principles, best suitable for i.e. different educational levels, different cultural and/or religious backgrounds, and gender.

The next two issues suggest an improvement of the science module itself, instead of new research lines.

How to increase attention for reflection?

The results of the pre- and post-test, discussed in chapter 4, showed that the science module did have an impact on the attitudes of most students; they showed an improvement on knowledge and understanding of the subject of genetics and biotechnology after the module. However, in chapter 5 we have discussed the discrepancy between the intended and implemented curriculum (van den Akker, 1988). We have indications that some of the teachers omitted (most of the) reflection activities (Knippels, Rijst, & Severiens, 2006). This is a familiar problem within educational research.

There are a number of barriers that hinder the actual implementation of reflection activities. One of them includes teachers' conceptions of teaching. Teaching is often primarily about direct transmission of knowledge or facts from teachers to students and consequently, mostly non-interactive teaching activities are employed. A 'radical' departure from these traditional conceptions and teaching activities is not always well integrated within teacher training programmes or within educational material. In other words, these programmes do not challenge teachers' conception of teaching towards a more social constructivist perception (in accordance with Smith, 2001). In order to successfully implement reflection activities, it seems important that teacher-training programmes do pay more attention to conceptions of teaching of the role of reflection activities.

Furthermore, in order to foster effective reflection, time and opportunity is needed. Reflection activities are mostly planned at the end of a course or activity, and therefore firstly skipped when time runs out, which is not unusual in the overloaded curricula of most schools.

When reconsidering the science module more emphasis should be placed on the implementation of the reflection learning activities in the classroom, thereby stressing the importance of this activity to teachers.

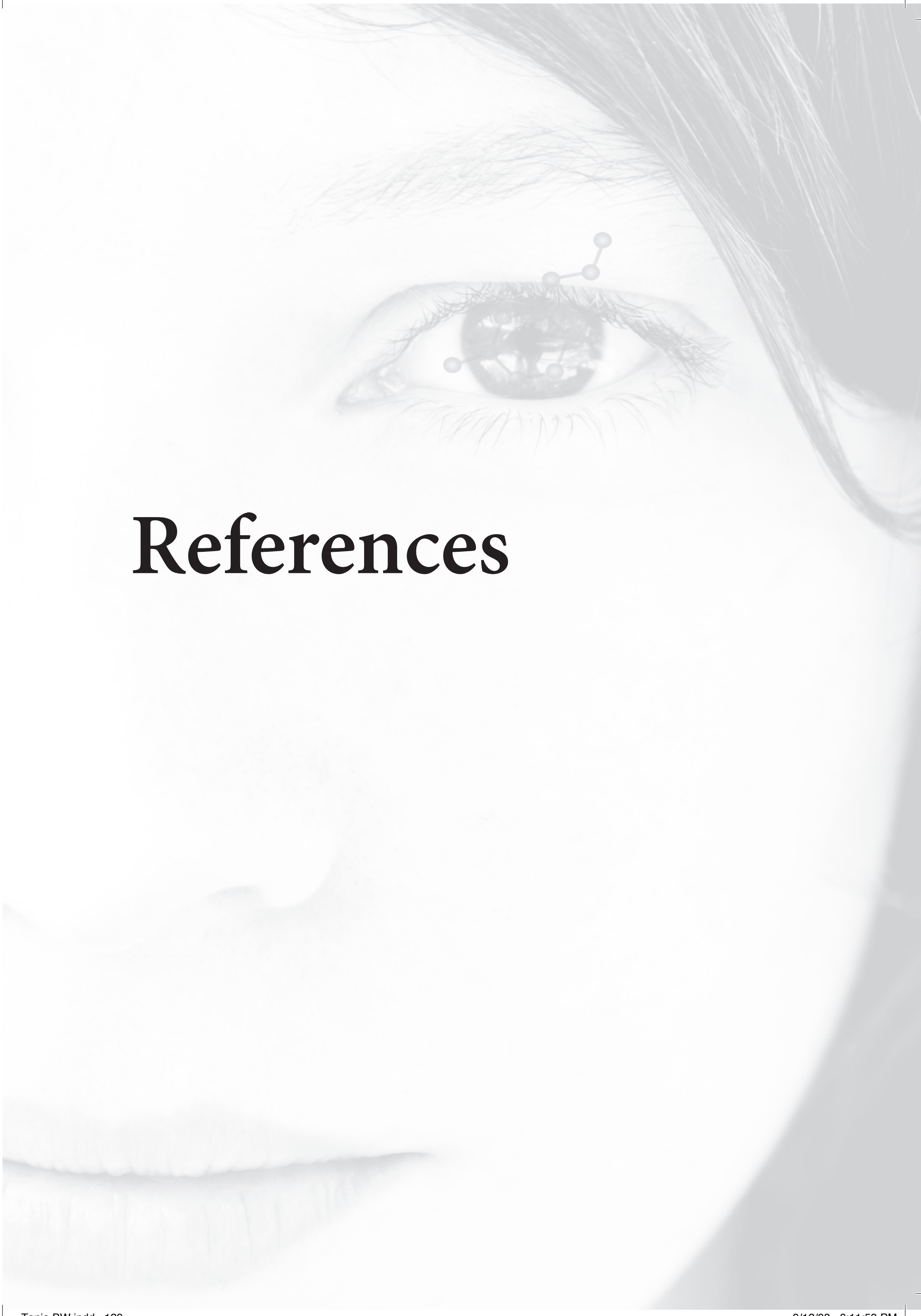
What should be done for whom?

The final remark we want to make concerns the different target groups of science education. On the one hand, there are the 16-year-old students in the second study who are in the pre-academic track. They are the students who have the potential to study sciences at more advanced levels: the vast majority of these students will enter higher education. The question is whether these students need science modules such as the one described in this thesis to become scientifically literate. Somewhere along the way in their educational and/or professional careers, they will undoubtedly pick up the necessary knowledge and experiences to be able to make informed decisions when confronted with issues of modern biotechnology. On the other hand, there are the secondary students in the vocational tracks. It is likely that these students, which represent 60% of all secondary school students in the Netherlands, do need science modules like this one to help them to become more scientifically literate in the complex field of modern biotechnology. Development of a module specifically designed for secondary school students in the vocational track, or students with relatively poor performance is needed.

Do attitudes towards modern biotechnology remain the same?

The most important questions that have been answered in this thesis are: what are secondary school students' attitudes towards modern biotechnology and do these attitudes change because of a science education module.

Because of the rapidity of developments in science and technology in this area, attitudes towards modern biotechnology are likely to change accordingly. It is therefore important to monitor students' attitudes by replicating both the qualitative as well as the quantitative parts of the studies as described in this thesis. Regularly monitoring attitudes provides relevant insights for the continuing development of science education modules. Adequately developing this and similar modules in science curricula, as well as the related teacher training programmes would help students' to develop their attitudes to more profound levels. It would help them to make well-informed decisions about issues related to science and technology, and become scientific literate members of society.



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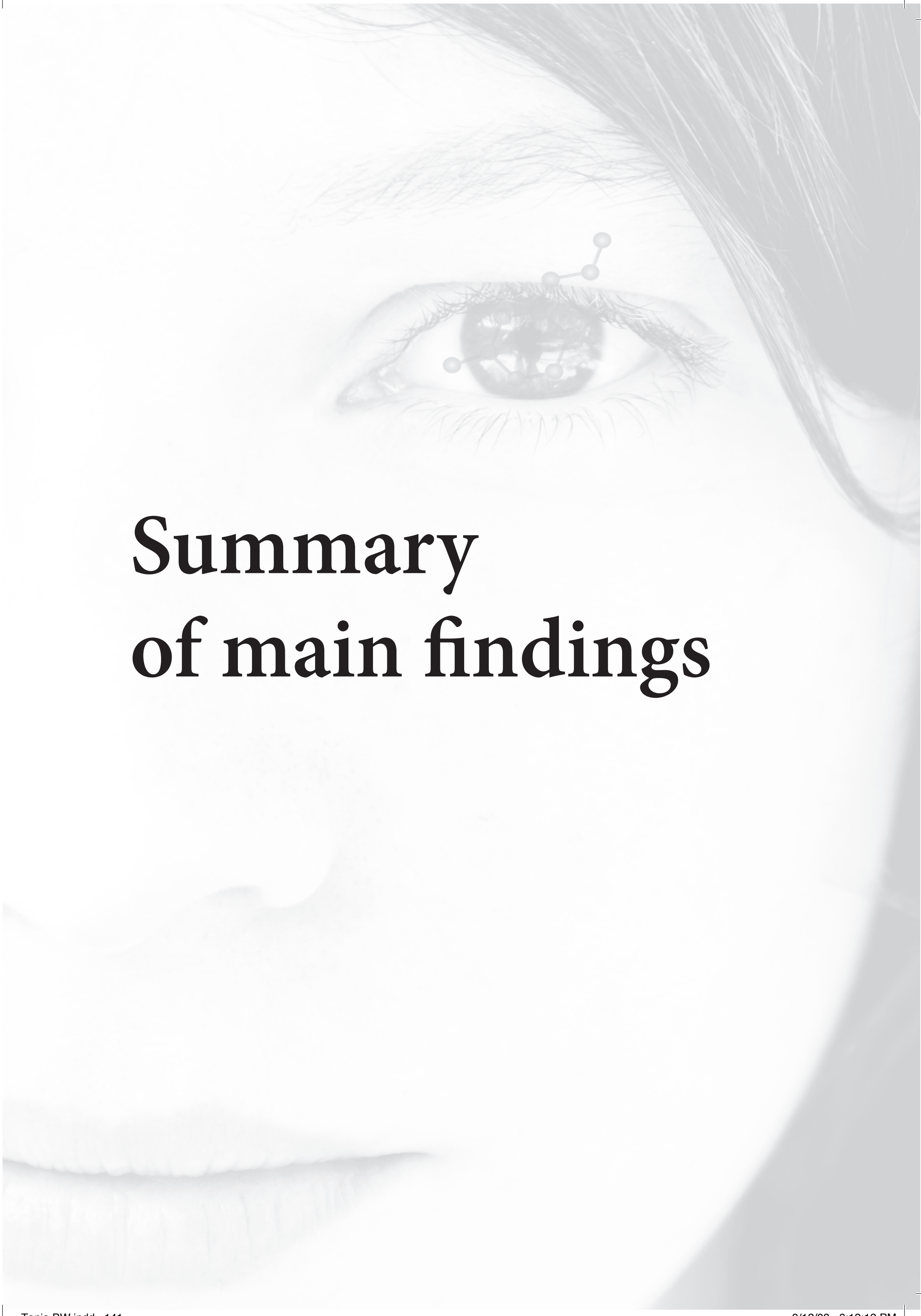

Summary of main findings

The studies in this thesis are concerned with the interaction of modern biotechnology and secondary school students. The first part of the thesis is concerned with the issue of what young people currently know about modern biotechnology, and what their views and opinions regarding this, are. In other words, what are their attitudes towards modern biotechnology?

The second part of the thesis focuses on the effects of a science education on the development of attitudes towards modern biotechnology.

In the first part of the thesis, two sub-studies are reported (each building on the same dataset) focussing on attitudes towards modern biotechnology of 16-year-old Dutch secondary school students.

In **Chapter 2,** the concepts of attitude and modern biotechnology and the practice of attitude measurement are discussed. It concerns the question what young people currently know about modern biotechnology, and what their underlying views and opinions are. In other words, what are the attitudes towards modern biotechnology of secondary school students? To this end, we used the tripartite theory of attitudes, which conceptualises attitude in terms of a cognitive, affective, and behavioural component. The development of an attitude-questionnaire and empirical study among 574 Dutch secondary school students is set out in detail. On the basis of an exploratory factor analysis, nine sub-factors underlying the three basic attitudinal components (cognition, affection and behavioural intentions) could be distinguished, thereby demonstrating that attitudes can be described as a multi-component concept.

In subsequent cluster analysis, four interpretable clusters, representing different groups of students were found. The four groups could be labelled as 'confident supporters' (22%), 'concerned sceptics' (18%), 'not sure's' (42%), and 'not for me's' (17%).

The 'confident supporters' consisted of a group of students that hold a very positive view towards modern biotechnology. They seemed to be good informed and not reluctant to accept biotechnology and its applications as part of their daily lives. This group was labelled as more scientifically literate. Just as the 'concerned sceptics', also a group of more scientifically literate students. These students had a solid knowledge base on basic biological and genetic concepts, but in opposition of the 'confident supporters' demonstrated a sceptical, concerned, and questioning stance towards claims made about modern biotechnology.

The smallest group, the 'not for me' students, was very negative about biotechnology. Their beliefs and affective reactions were very negative. Unfortunately, this negative perspective was built on a poor knowledge base and weak understanding of the accompanying subjects of modern biotechnology. A group we considered to be poor scientifically literate.

The last cluster, the so-called 'not sure' group, held the most students. Their views tended to be rather indistinct; not sure if they were against or in favour of modern biotechnology and their overall understanding of the subjects left something to be desired. This is another group of less scientific literate secondary school students.

The results clarified that with respect to a complex subject such as modern biotechnology, each of the attitude components has its unique contribution to the overall attitude, thereby indicating that there is a diverse appraisal of modern biotechnology amongst secondary school students.

Chapter 3 describes the relationship between these four different attitude groups of secondary school students and their background- and underlying value factors associated with attitude towards modern biotechnology. Descriptive and multinomial logistic regression analyses were conducted to examine these relationships.

The results in this study confirmed former results on gender differences: boys seemed more often confident supporters of biotechnology, whereas girls were more often concerned sceptics or not sure what to think of it. In this study, the differences between boys and girls could not be explained by the difference in interest in science, but by a different way of considering ethical matters of biotechnology.

Overall, the ethical points of view of students were strongly related to their overall attitudes towards modern biotechnology. Just like the perception of benefits of modern biotechnology and several school factors; level of education and choosing biology as final-examination subject, showed a strong and significant relationship with the different attitudes. The results revealed that the higher the level of education, the more positive the students were towards modern biotechnology ('confident supporters'), and quite the reverse, students in lower education levels were more negative about biotechnology ('not for me').

The outcomes of the first study gave rise to the research questions that were investigated in a second empirical study; the effects of science education as a means to develop students' attitudes towards modern biotechnology. In other words, to improve scientific literacy. Again two studies are reported, investigating the effects of an innovative science education module on students' attitudes towards modern biotechnology (as a measure of scientific literacy) using both quantitative (Chapter 4) and qualitative (Chapter 5) methods of research.

In **Chapter 4,** the impact of a four-lesson science module on the four different groups of students was evaluated. The science module on a socioscientific subject (cancer and modern biotechnology) consisted of several design principles, inspired by a social constructivist perspective on learning. According to this perspective, we argued that this module might help students to create a more balanced attitude towards biotechnology; meaning more 'confident supporters and concerned sceptics'. Approximately 365 secondary school students participated in a quasi-experimental design study (treatment, control groups and pre- and post-tests) to examine the effects of the science module on their attitudes. Chi-square tests showed that the science module had a small but significant effect on attitudes, although predominantly towards a more supportive ('confident supporter') and not towards a more critical stance ('concerned sceptic').

However, and contrary to our expectations, a rather substantial group of the students had moved internally from the 'confident supporter' group or the 'concerned sceptic' group, to the 'not-sure' group.

Finally, in **chapter 5,** a qualitative research method was used to investigate the (unexpected) effects of the science module in more detail. This chapter reported on a case study on attitudes and attitude changes towards modern biotechnology of 16 secondary school students. Pre- and post-attitude questionnaires, classroom observations, and pre- and post-module interviews were used to follow students' attitudinal changes. Findings showed an increase in attitudes that were more positive or more ambivalent. The more concerned and negative students claimed that the confrontation with the science module made them doubt their scepticism. Several students indicated that only after the science module, they realised that modern biotechnology is already part of their everyday life. In addition, the majority of the students showed less worries about modern biotechnology after the module, and claimed to be more certain of what to do when confronted with modern biotechnology. On the other hand, some sceptical students said to have moved from a critical certainty about what they believed they understood about biotechnology, to a more reflective awareness of the complexity of modern biotechnology. This made them more doubtful, since they had not been confronted with 'both sides' of biotechnology before, resulting in a 'not sure' attitude.

Based on the findings presented in the studies of this thesis, several conclusions can be put forward.

A first general conclusion is that we were able to demonstrate that attitudes towards biotechnology is a concept with a complex underlying structure of different cognitive, affective and behavioural features. These features interact in a certain way, resulting in different kind of attitudes among the students. Thereby it was shown that the groups of students that somehow lag behind in the educational system, girls (in science classes), minority groups and students of the lower educational levels were overrepresented in the attitude-groups characterised as deficiently scientific literate.

Another main conclusion of this thesis is that when students are offered well thought-out and balanced science education, it does stimulate them to base their attitudes towards modern biotechnology upon a broader cognitive foundation, a more considered affective association, and it enhances the ability to know what to do or act when confronted with it. This is in particular important for the large group of secondary school students that are unsure of their point of view towards modern biotechnology.

Samenvatting van de belangrijkste resultaten

De studies in dit proefschrift gaan in op twee vraagstukken die betrekking hebben op de interactie tussen moderne biotechnologie en middelbare scholieren. De eerste vraag is: hoe denken zestienjarige middelbare scholieren over moderne biotechnologie? Wat weten ze er van en wat zijn hun achterliggende gedachten hierover? Met andere woorden: wat is hun 'attitude' ten aanzien van moderne biotechnologie

In de tweede helft van dit proefschrift wordt gekeken of en hoe wetenschapsonderwijs leerlingen kan helpen, niet alleen hun kennis op dit gebied te vergroten, maar ook hun attitudes te verdiepen en te verbreden.

In het eerste gedeelte van dit proefschrift worden twee deelstudies rond het eerste vraagstuk beschreven, welke zijn gebaseerd op één dataset.

In **hoofdstuk 2** worden de begrippen attitude en biotechnologie uiteengezet. Ook wordt de onderzoeksprocedure, de ontwikkeling van de 'attitudevragenlijst' en de empirische studie onder 574 Nederlandse middelbare scholieren, in detail beschreven.

Om te kunnen achterhalen wat jongeren eigenlijk weten van moderne biotechnologie, hoe ze erover denken en wat hun meningen zijn, is gebruik gemaakt van de driedelige theorie van attitudes. Volgens deze theorie bestaat een attitude uit een cognitieve, een affectieve en een gedragscomponent. Aan de hand van deze conceptualisatie is een attitudevragenlijst ontwikkeld en afgenomen onder de scholieren.

Door middel van exploratieve factoranalyses werden onder elke van de drie basiscomponenten; cognitie, affectie en gedragsintenties, drie subcomponenten gevonden. Hiermee werd aangetoond dat een attitude als een multi-dimensionaal concept kan worden beschouwd.

In een hierop volgende clusteranalyse werden vier groepen scholieren onderscheiden. Deze werden beschreven als de 'voorstanders' (22%), 'bezorgde sceptici' (18%), 'onwetenden' (42%) en de 'afwijzenden' (17%).

De groep van de 'voorstanders' bestond uit leerlingen met een zeer positieve kijk op moderne biotechnologie. Ze leken goed op de hoogte en niet terughoudend in het accepteren van biotechnologie en toepassingen daarvan als deel van hun dagelijks leven. Deze leerlingen konden worden betiteld als *scientifically literate*[1].

Dat gold eveneens voor de 'bezorgde sceptici'. Ook deze scholieren leken te beschikken over een solide basiskennis van de biologie en genetica, maar in tegenstelling tot de 'voorstanders' hadden zij een meer bezorgde en twijfelende houding ten aanzien van gemaakte claims over moderne biotechnologie.

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[1] De letterlijke Nederlandse vertaling 'wetenschappelijke geletterdheid' dekt de lading niet helemaal. De term *scientific literacy* wordt tegenwoordig wereldwijd gebruikt als een overkoepelende term voor de curriculumdoelen van wetenschaps- en techniekeducatie. Vandaar dat in deze samenvatting verder over '*scientific literacy*' wordt gesproken.

De kleinste groep, bestaande uit de 'afwijzenden', was erg negatief over biotechnologie. Deze afwijzende houding was gebaseerd op een slechte cognitieve basis, oftewel weinig kennis van moderne biotechnologie en aanverwante onderwerpen. Deze groep scholieren werd dan ook beschouwd als minder *scientifically literate*.

Het laatste cluster, de groep van de 'onwetenden', omvatte de meeste scholieren. Hun opvattingen waren nogal onbestemd. Ze wisten niet zeker of ze nu voor of tegen moderne biotechnologie moesten zijn en hun algemene begrip van de onderwerpen liet te wensen over. Deze groep is daarom eveneens beschreven als minder *scientifically literate*.

De resultaten tonen aan dat elke afzonderlijke attitudecomponent een unieke bijdrage levert aan de algehele houding ten opzichte van een complex onderwerp als moderne biotechnologie. Dat betekent dat er nogal wat verschillende waarderingen voor moderne biotechnologie zijn onder middelbare scholieren.

Hoofdstuk 3 beschrijft de relaties tussen de vier verschillende groepen middelbare scholieren, hun achtergronden en onderliggende waarden geassocieerd met attitudes ten aanzien van moderne biotechnologie. Om deze relaties te bestuderen, zijn descriptieve en multinomiale logistische regressieanalyses uitgevoerd.

De resultaten hiervan bevestigen eerdere bevindingen over de sekseverschillen: jongens blijken vaker 'voorstanders' te zijn, terwijl meisjes vaker 'bezorgde sceptici' zijn of niet goed weten wat ze moeten vinden van moderne biotechnologie.

In deze studie werd het onderscheid tussen jongens en meisjes niet verklaard door een verschil in interesse in wetenschap en technologie, maar door een andere manier van nadenken over de ethische aspecten van biotechnologie. De ethische standpunten van de scholieren waren over het algemeen sterk gerelateerd aan hun algehele attitude tegenover moderne biotechnologie. Deze sterke relatie met attitude gold eveneens voor de perceptie van voordelen van biotechnologie, het schoolniveau en het hebben van biologie als examenvak.

De resultaten laten zien dat hoe hoger het opleidingsniveau is, hoe positiever de leerling tegenover moderne biotechnologie staat. Ook het omgekeerde geldt; leerlingen in de lagere opleidingsniveaus oordelen relatief negatief over moderne biotechnologie.

De bevindingen van deze eerste studies riepen nieuwe vragen op, die aanleiding gaven tot een tweede empirische studie. Centrale vraag hierin luidde: wat zijn de effecten van wetenschapseducatie, als een manier om attitudes van scholieren ten aanzien van moderne biotechnologie te ontwikkelen? Met andere woorden, hoe kan wetenschapsonderwijs *scientific literacy* verbeteren?

De effecten van een innovatieve onderwijsmodule op de attitudes van leerlingen ten aanzien van moderne biotechnologie (als een maat voor *scientific literacy*) zijn op twee manieren bestudeerd. Enerzijds wordt gebruik gemaakt van kwantitatieve methoden (hoofdstuk 4) en anderzijds van kwalitatieve methoden (hoofdstuk 5).

In **hoofdstuk 4** wordt de impact van de onderwijsmodule op de vier verschillende typen scholieren geëvalueerd. De module behandelde zogenaamd socio-wetenschappelijk onderwerp ('kanker en moderne biotechnologie') en was opgebouwd op basis van diverse ontwerpprincipes, geïnspireerd op een sociaalconstructivistisch perspectief op leren. Uitgaande van dit perspectief, beargumenteerden wij dat deze module scholieren wellicht zou helpen om een meer evenwichtigere attitude ten aanzien van biotechnologie te creëren. Anders gezegd: deze module zou scholieren kunnen helpen om 'voorstanders' of 'bezorgde sceptici' te worden.

Circa 400 middelbare scholieren namen deel aan het onderzoek, welke een quasi-experimentele opzet had (effect van 'experiment', controle groepen en voor- en natesten). Chi-kwadraat testen lieten zien dat de module een klein, maar significant effect had op de attitudes van leerlingen. Dit effect bleek overwegend ten gunste van de toch al positieve leerlingen te zijn en niet op de attitude van de meer kritische scholieren. Opvallend – en tegen onze verwachting in – was dat een tamelijk grote groep scholieren was opgeschoven van de 'voorstanders' en de 'bezorgde sceptici' naar de 'onwetenden'.

Tot slot wordt in **hoofdstuk 5** een kwalitatieve detailstudie naar de (onverwachte) gevolgen van de onderwijsmodule beschreven. Het beschrijft casusstudies naar attitudes en attitudeveranderingen van zestienjarige scholieren ten aanzien van moderne biotechnologie. Voor- en nameting van vragenlijsten, klassenobservaties en interviews voor en na het volgen van de module zijn gebruikt om de veranderingen in de attitude van de leerlingen te volgen.

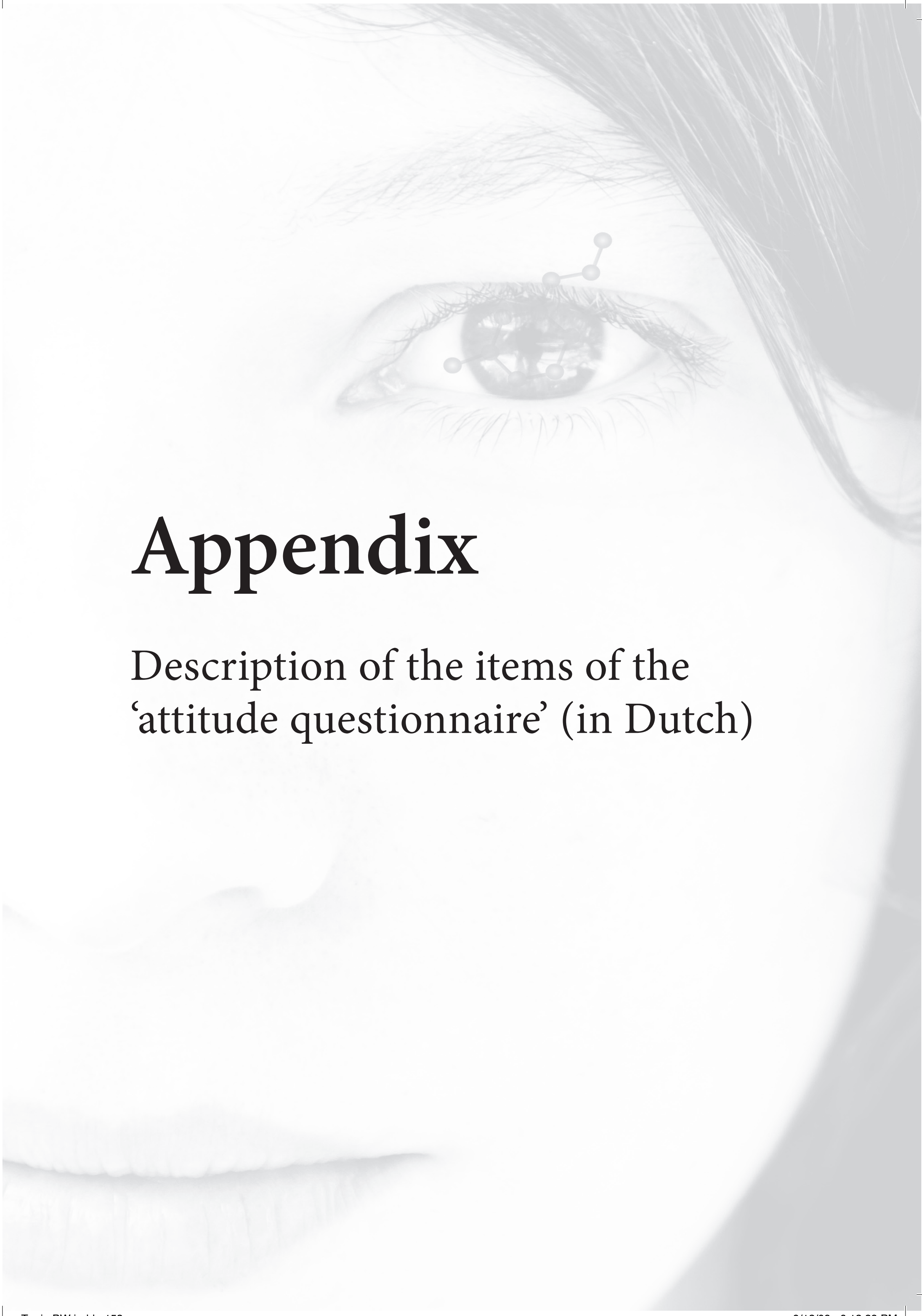
De module bleek te leiden tot een toename van meer positieve en meer ambivalente attitudes. Bezorgde en negatieve leerlingen gaven aan dat de confrontatie met de onderwijsmodule ze vraagtekens deed plaatsen bij hun achterdocht. Meerdere scholieren zeiden bovendien zich pas na het volgen van de module te realiseren dat biotechnologie al lang deel uitmaakt van hun dagelijkse leven. De meerderheid van de leerlingen was na de lessen minder bezorgd en dacht beter in staat te zijn beslissingen te nemen over toepassingen van moderne biotechnologie, wanneer ze daarmee in aanraking zouden komen.

Aan de andere kant raakten sommige scholieren juist meer aan het twijfelen. Enkele sceptische leerlingen merkten op dat ze minder zeker waren over hun kennis en zich bewuster waren geworden van de complexiteit van moderne biotechnologie. Ze waren nooit eerder geconfronteerd met zowel de positieve als negatieve kanten van biotechnologie, raakten in de war en schoven om die reden meer richting de groep van de 'onwetenden'.

Gebaseerd op de bevindingen die in dit proefschrift zijn neergezet, kunnen verscheidene conclusies getrokken worden.

Een eerste algemene conclusie is dat er kon worden aangetoond dat attitude ten aanzien van moderne biotechnologie een concept met een complexe onderliggende structuur is, bestaande uit verschillende cognitieve, affectieve en gedragseigenschappen. Deze eigenschappen werken op een bepaalde manier op elkaar in, resulterend in verschillende soorten attitudes onder de leerlingen. Daarnaast kon geconcludeerd worden dat de groepen leerlingen die het op de een of andere manier minder goed doen in het onderwijssysteem; meisjes (in bètavakken), minderheidsgroepen en leerlingen uit de lagere onderwijsniveaus, sterk vertegenwoordigd zijn in de attitudegroepen die als minder *scientific literate* worden gekenmerkt.

Een andere belangrijke conclusie die uit de studies is voortgekomen, is dat wanneer leerlingen goed doordacht en evenwichtige wetenschappelijke onderwijsmodules wordt aangeboden, het hen stimuleert om hun attitudes ten aanzien van moderne biotechnologie op een bredere cognitieve basis en een meer overwogen affectieve reactie te baseren. Daarnaast geeft het hen meer houvast om te beslissen wat te doen of hoe te handelen wanneer zij zichzelf geconfronteerd zien met toepassingen van moderne biotechnologie. Dit is in het bijzonder belangrijk voor de grote groep van middelbare scholieren die onzeker is over hun standpunt over moderne biotechnologie.



Appendix

Description of the items of the ‘attitude questionnaire’ (in Dutch)

Please note that the questionnaire was developed in Dutch and was only administered to Dutch-speaking student populations. An English version of this questionnaire needs to be tested first in English-speaking student populations to investigate validity. Moreover, the vast and quickly developing field of research and applications of modern biotechnology ask for a regular update of the items used in questionnaires.

Cognitieve component

Biologie en erfelijkheid; n = 9, α = 0.63, M = 7.10 (1.8)

DNA is de afkorting van Draaiend Nucleïne Acid

Een mens heeft 23 paren chromosomen in een celkern.

De chromosomen in de cellen van je ogen bevatten de informatie voor je oogkleur

De chromosomen in de cellen van je nieren bevatten de informatie voor je oogkleur

AIDS is een genetische ziekte

Door goede hygiëne kun je genetische ziekten voorkomen.

Kinderen lijken op hun ouders omdat zij dezelfde soort rode bloedlichaampjes hebben.

Een echtpaar heeft van de dokter gehoord dat ze een kans van 1 op 4 hebben (1:4), op een kindje met een erfelijke ziekte. Dit betekent dat als het eerste kind de ziekte heeft, de volgende drie kinderen dat niet zullen hebben.

Apen hebben driemaal minder genen dan mensen.

Biotechnologie; n = 17, α = 0.71, M = 13.80 (1.8)

Genetische modificatie is het doelbewust veranderen van de erfelijke eigenschappen van levende wezens.

Genetisch gemodificeerde dieren zijn altijd kleiner dan gewone dieren.

Bij de productie van geneesmiddelen en hormonen wordt gebruik gemaakt van biotechnologie.

Bij de bereiding van yoghurt worden bacteriën gebruikt.

Xenotransplantatie is het overbrengen van een (vreemd) dierlijk orgaan in een menselijk lichaam.

Als je genetisch gemodificeerd fruit eet, kunnen jouw genen ook genetisch gemodificeerd raken.

Gewone tomaten hebben, in tegenstelling tot genetisch gemodificeerde tomaten, geen genen.

Het is mogelijk om genen van mensen over te brengen naar bacteriën.

Het is mogelijk om de erfelijke eigenschappen van planten zo te veranderen dat die planten zelf bestrijdingsmiddelen tegen bepaalde insecten maken.

Het is mogelijk om erfelijke eigenschappen van een dier zo te veranderen dat die dieren menselijke groeihormonen gaan maken.

Is het mogelijk…tijdens de zwangerschap vast stellen of het kindje een mongooltje is?

Is het mogelijk…Het veranderen van de erfelijke eigenschappen van een baby voordat het geboren is, zodat het kind slimmer, sterker en knapper zal worden?

Is het mogelijk…Tijdens de zwangerschap bepalen of de baby een hoog IQ of intelligentie zal hebben?

Is het mogelijk…Met genetische testen er achter komen of iemand een hogere dan gemiddelde kans heeft om een bepaalde soort kanker te ontwikkelen.

De overheid moet altijd toestemming geven voordat een genetisch gemodificeerde plant op de akkers gezet mag worden.
Het is in Nederland verboden om menselijke embryo's te klonen.
Is het mogelijk…Het klonen van mensen?

Evaluatieve kennis van biotechnologie/ 'beliefs' over biotech; n = 5, α = 0.70, M = 3.09 (0.64)

Genetisch gemodificeerd voedsel biedt uitkomsten bij het oplossen van hongersnood in derde wereld landen.
Biotechnologie maakt ons leven gezonder, gemakkelijker en comfortabeler.
Dankzij biotechnologische vooruitgang, zullen de natuurlijke rijkdommen van de aarde niet uitgeput raken.
Genetisch gemodificeerd voedsel is een bedreiging voor toekomstige generaties.
Wat de gevaren van genetisch modificeren ook mogen zijn, verder onderzoek zal deze vast wel oplossen.

Affectieve component

Basisemoties; n = 13, α = 0.76, M = 3.00 (0.58)

ik vind genetisch onderzoek bij mensen erg twijfelachtig.
Ik vind het genetisch modificeren van voedsel eng.
Het genetisch modificeren van dieren is *niet* zielig.
Dieren hebben rechten die de mens niet mag schenden.
Genetische modificeren is bedreigend voor de natuur.
Genetisch onderzoek bij mensen is voor God spelen.
Al deze technieken kunnen makkelijk misbruikt worden.
Klonen is veilig
Het genetisch modificeren van bacteriën kan niet goed zijn.
Ik vind dat het allemaal te snel gaat.
Genetisch modificeren is *goed.*
Ik vind al die toepassingen te ingewikkeld om er iets van te vinden.
Biotechnologie laat me ongeboeid

Noodzakelijk of onontkoombaar; n = 9, α = 0.76, M = 3.12 (0.62)

Biotechnologie is absoluut noodzakelijk.
Het genetisch modificeren van planten overschrijdt grenzen waar we niet overheen mogen gaan.
Het eten van genetisch gemodificeerd voedsel is *gevaarlijk*
Genetisch onderzoek bij dieren heeft voordelen voor de gezondheid van de mens.
Genetisch onderzoek bij dieren is absoluut *onnodig*
Genetisch modificeren hoort nu eenmaal bij deze tijd.
Genetisch onderzoek bij de mens is *nutteloos*.
Genetisch onderzoek bij mensen is absoluut noodzakelijk.
Ik heb wel vertrouwen in de wetenschap.

Zorgen; n = 5, α = 0.79, M = 2.97 (0.79)

Maak je je zorgen over…Moderne biotechnologie
In vitro bevruchting
Genetisch onderzoek
Genetisch modificeren
Kloneren

Gedragsintenties component

Consumeren onder bepaalde voorwaarden/ eigen belang; n = 5, α = 0.78, M = 3.09 (0.82)

Als er etenswaren in de winkel komen, die gemaakt zijn met biotechnologische technieken, zou ik ze kopen

Als het eten in het restaurant waar ik eet ingrediënten bevat die genetisch gemodificeerd zijn, maakt me dat niet uit.

Ik zou genetisch gemodificeerd voedsel kopen als het goedkoper is dan gewoon voedsel.

Ik zou genetisch gemodificeerd voedsel kopen als het beter zou smaken dan gewoon voedsel.

Ik zou genetisch gemodificeerd voedsel eten als het minder vet bevat dan gewoon voedsel.

Medische intenties (testen)n = 4, α = 0.74, M = 3.10 (0.83)

Een genetische test willen tijdens je eigen of je vriendin/vrouw haar zwangerschap?

Een genetisch onderzoek willen ondergaan om er achter te komen of je op latere leeftijd een ernstige ziekte krijgt.

Als tests aantoonden dat je waarschijnlijk een ernstige genetische ziekte zou krijgen later, therapie ondergaan om die genen te corrigeren voordat je de ziekte echt krijgt?

Als je een kind zou hebben met een ernstige of dodelijke genetische ziekte, therapie laten ondergaan om die genen te verbeteren/veranderen?

Consumeren onder bepaalde voorwaarden/ kritische voorwaarden; n = 3, α = 0.74, M = 3.60 (0.90)

Ik zou genetisch gemodificeerd voedsel kopen als het minder gifresten inzitten dan bij gewoon voedsel.

Ik zou genetisch gemodificeerd voedsel kopen als milieuvriendelijker gekweekt is dan gewoon voedsel.

Ik zou genetisch gemodificeerd voedsel eten als wetenschappelijk is aangetoond dat het onschadelijk is.

Ethische overwegingen

Medische (of specialistische) toepassingen; n = 15, α = 0.90

gebruikt worden voor medische doeleinden.

gebruik van genetisch onderzoek voor de verbetering van diagnoses voor ziekten bij mensen.

bestuderen van ziekten met behulp van genetisch onderzoek.

Testen van ongeboren baby's voor ernstige ziekten.

Vaststellen van vaderschap of andere familieverhoudingen.

Bestuderen van evolutie, voorouders en bevolking met behulp van genetisch onderzoek.

Veranderen van erfelijke factoren voor…Het genezen van een dodelijke ziekte, zoals kanker.

Verbeteren van kapotte genen bij mensen.

Veranderen van erf. fact. voor…Het verminderen van het risico om op latere leeftijd een ernstige ziekte te krijgen.

Veranderen erf.fact. voor…Het beschermen van mensen voor het krijgen van een ernstige erfelijke ziekte (zoals kanker).

Veranderen van erfelijke factoren voor…Het voorkomen dat iemand een niet fatale ziekte erft (zoals suikerziekte).

Het introduceren van menselijke genen in dieren om organen te produceren voor menselijke transplantaties, zoals in varkens voor harttransplantaties.

Gebruiken van genetische testen om ziekten te ontdekken die wij van onze ouders kunnen overerven, zoals taaislijmziekte
voor/tegen... medicijnen gemaakt dmv genetische modificatie
Identificeren van criminelen door de politie, dmv van DNA dat op de plek van het misdrijf is gevonden.

kwalitatief gebruik van biotechnologie; n = 14, α = 0.90

Het gebruik van de moderne biotechnologie in de productie van voedsel, om bijvoorbeeld een hogere voedingswaarde, langere houdbaarheid of betere smaak te krijgen.
voor/tegen... genetisch gemodificeerde groenten (tomaten, aardappelen, e.d.)
voor/tegen...genetisch gemodificeerde melkproducten (melk, boter, e.d.)
voor/tegen...genetisch gemodificeerd vlees (vlees, vis)
voor/tegen...genetisch gemodificeerde micro-organismen in wasmiddelen
voor/tegen...het gebruik van gemod. micro-organismen voor een efficiëntere afbraak van afval.
voor/tegen... Kleren die gemaakt zijn van genetisch gemodificeerd katoen
Genetisch modificeren mag ... gebruikt worden op planten.
…gebruikt worden op bacteriën.
…gebruikt worden om gewassen te krijgen die beter tegen ziekten kunnen
…gebruikt worden om bacteriën te krijgen die olie op kunnen ruimen. (industrie)
Inbouwen van genen van micro organismen in maïs zodat het beter bestand is tegen ongedierte.
Inbouwen van genen van bacteriën in planten.
Gebruik van genetisch gemodificeerde koeien voor de productie van medicijnen.

Biotech toepassen zonder 'levens te redden'; n = 16, α = 0.88

Veranderen van erfelijke factoren voor…Verbeteren/ veranderen van lichamelijke kenmerken, zoals oogkleur.
Veranderen van erfelijke factoren voor…Verbeteren van de intelligentie.
Veranderen van erfelijke factoren voor…Het aardiger maken van mensen.
Stellen die geen kinderen kunnen krijgen mogen gebruik maken van het klonen van embryo's.
Genetische modificatie mag gebruikt worden op dieren.
…gebruikt worden op mensen.
…gebruikt worden op dieren voor gezonder vlees (bijv. minder vet).
…gebruikt worden om grotere vissen te krijgen voor hengelaars.
…gebruikt worden om koeien meer melk te laten produceren.
…gebruikt worden om mooiere en grappige dieren te maken (lichtgevende vissen)
Inbouwen van genen van planten in dieren.
Inbouwen van genen van mensen in dieren
voor/tegen...het toevoegen van genen aan gist om lekkerder brood te maken
gebruikt worden om tomaten te maken die beter smaken
Veranderen van genen van tomaten zodat ze langer houdbaar zijn.
Een vrouw mag een 4 maand oude foetus aborteren als deze aangeboren (genetische) afwijkingen heeft

Interesse

Intrinsieke interesse; n = 5, α = 0.73

Ik vind wetenschap interessant.
Ik wil later een beroep in de wetenschap of technologie

Ik wil er mijn studie van maken
Ik vind kennis over biotechnologie belangrijk voor mezelf.
Door mij leraar biologie of ANW vind ik dit onderwerp interessant

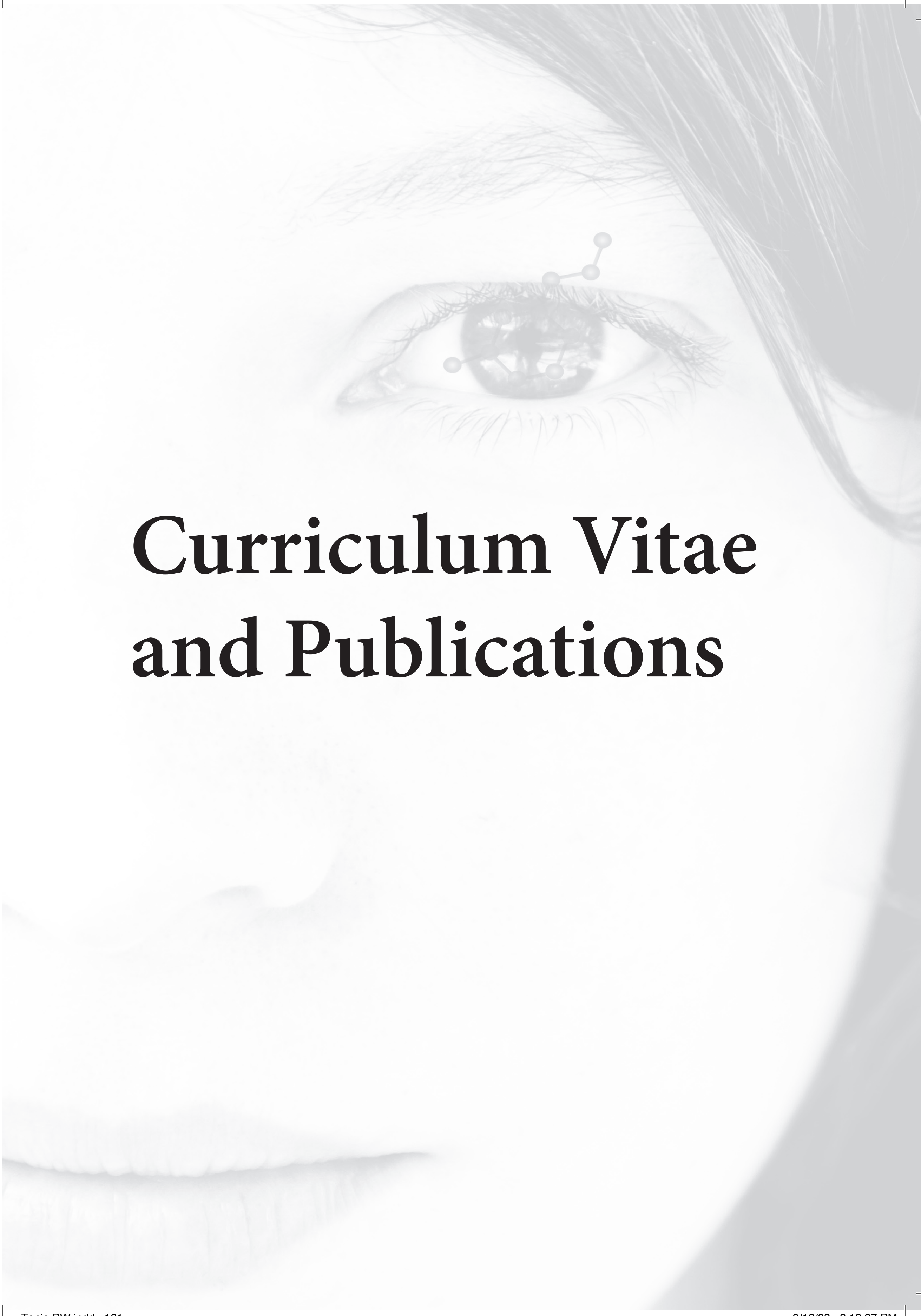
Nut & Risico overwegingen

Nut; n = 13, α = 0.78

Genetisch gemodificeerd voedsel biedt uitkomsten bij het oplossen van hongersnood in derde wereld landen.
De wetenschappelijke en technologische vooruitgang zal helpen om ziekten zoals AIDS, kanker, enz. te genezen.
Biotechnologie maakt ons leven gezonder, gemakkelijker en comfortabeler.
De voordelen van wetenschap zijn groter dan de schadelijke gevolgen die het kan hebben.
Dankzij biotechnologische vooruitgang, zullen de natuurlijke rijkdommen van de aarde niet uitgeput raken.
Belangrijke taken van wetenschap en biotechnologie zijn: Ziekten helpen voorkomen
Belangrijke taken van wetenschap en biotechnologie zijn: Het ontwikkelen van nieuwe producten
Belangrijke taken van wetenschap en biotechnologie zijn: Verbeteren van het milieu
Belangrijke taken van wetenschap en biotechnologie zijn: Ziekten beter te behandelen
Belangrijke taken van wetenschap en biotechnologie zijn: De wereldbevolking te voeden
Het gebruik van de moderne biotechnologie in de productie van voedsel, om bijvoorbeeld een hogere voedingswaarde, langere houdbaarheid of betere smaak te krijgen (nut?)
Het introduceren van menselijke genen in dieren om organen te produceren voor menselijke transplantaties, zoals in varkens voor harttransplantaties.(nut?)
Gebruiken van genetische testen om ziekten te ontdekken die wij van onze ouders kunnen overerven, zoals taaislijmziekte (nut?)

Risico; n = 10, α = 0.60

Al die nieuwe technieken zijn onnodig omdat de oude ook goed werken.
Het eten van genetisch gemodificeerd voedsel zal slecht zijn voor mijn gezondheid.
Deze nieuwe ontwikkelingen zijn schadelijk voor landen in de derde wereld.
De gevolgen zullen niet meer terug te draaien zijn.
Deze nieuwe technieken kunnen ongevallen veroorzaken.
De kennis van wetenschappers geeft hen macht waardoor ze gevaarlijk kunnen worden.
Het gebruik van de moderne biotechnologie in de productie van voedsel, om bijvoorbeeld een hogere voedingswaarde, langere houdbaarheid of betere smaak te krijgen.(risico?)
Het introduceren van menselijke genen in dieren om organen te produceren voor menselijke transplantaties, zoals in varkens voor harttransplantaties.(risico?)
Gebruiken van genetische testen om ziekten te ontdekken die wij van onze ouders kunnen overerven, zoals taaislijmziekte(risico?)
De overheid beschermt de mensen genoeg tegen eventuele risico's van moderne biotechnologie



Curriculum Vitae and Publications

Tanja Klop is born on July 14, 1975 in Hendrik Ido Ambacht. She completed her secondary education in 1994 at the Walburg College in Zwijndrecht. In May 2001, she received her Master of Science degree in Biology at the Catholic University Nijmegen. After her graduation, she worked as a research analyst at a Bioscience research laboratory. From February 2003, she started her PhD research at the Rotterdam Institute for Social Policy research (Risbo). Her research concerned secondary school students' attitudes towards modern biotechnology and the role of science education herein. While still working on her thesis, in July 2007 she took on a temporarily job as a researcher at the University of Utrecht. Her research there concerned a comparative case study on the differences between more traditional biology education and on concept-context situated biology education. At the beginning of 2008, she was offered a position of post-doctoral researcher at the working group on Biotechnology and Society of the department of Biotechnology of the Delft University of Technology, where she started working at the beginning of June. Here she will be doing research on user-producer interactions in functional genomics innovations.

Publications, Presentations and Proceedings

Publications

Klop, T., & Severiens, S. E. (2008). Students with a view; Explaining attitudes towards modern biotechnology. In M. Hammann, M. Reiss, C. Boulter & S. D. Tunnicliffe (Eds.), *Biology in Context; Learning and teaching for the twenty-first century* (pp. 101-112). London: Institute of Education, University of London.

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Klop, T. & Severiens, S.E. (2005*). Exploration of attitudes towards biotechnology of Dutch secondary school students.* Paper presented at the Fifth International ESERA Conference on Contributions of Research to Enhancing Students Interest in Learning Science. 28-08-2005, Barcelona, Spain

Klop, T., S.E. Severiens & M.C.P.J. Knippels, (2005*). Exploration of attitudes towards biotechnology of Dutch secondary school students.* In: Proceedings of the Fifth International ESERA Conference on Contributions of Research to Enhancing Students Interest in Learning Science. 28-08-2005, Barcelona, Spain