Kiel

Working Papers

Kiel Institute
for the World Economy

Self-selection, socialization, and risk perception: an empirical study

by Ursula Weisenfeld and Ingrid Ott

No. 1555| September 2009

Web: www.ifw-kiel.de

Kiel Institute for the World Economy, Düsternbrooker Weg 120, 24105 Kiel, Germany

Kiel Working Paper No. 1555| September 2009

Self-selection, socialization, and risk perception: an empirical study

Ursula Weisenfeld and Ingrid Ott

Abstract

We analyze students' knowledge and risk perception of four technologies. The aim is to find out whether there is a relationship between area of study (self-selection) and progress of study (socialization) on the one hand and risk perception of technologies regarding health, environment and society on the other. The four technology fields under study are renewable energies, genetic engineering, nanotechnology and information and communication technologies (ICT). Key results are: Irrespective of study area, study progress and gender, genetic engineering has the highest perceived risk and renewable energies has the lowest. This holds for all the risks studied (environmental, health, societal risks). For most risk perception variables, advanced students perceive lower risks than beginners, and students in a technical study area perceive lower risks than students in a non-technical area. Factor analyses show that common dimensions of risk are the technological areas and not the type of risk. Regression analyses show that the variables influencing perceived risks vary between the technological fields.

Keywords: technologies, risk perception, self-selection, socialization

JEL-code: O33

Acknowledgements: We would like to thank participants of the 2009 S.NET conference as well as participants of the research seminars at the IfW and the TU Hamburg for valuable comments.

Ursula Weisenfeld

Leuphana University Lueneburg
Scharnhorststr. 1
21335 Lueneburg, Germany
Telephone: +49 4131-677- 2120
E-Mail: weisenfeld@uni.leuphana.de

Ingrid Ott

Kiel Institute for the World Economy
24100 Kiel, Germany
E-Mail: ingrid.ott@ifw-kiel.de

and Hamburg Institute of International Economics (HWWI)

Self-selection, socialization, and risk perception of technologies: An empirical study

Ursula Weisenfeld[a]
Ingrid Ott[b]

[a]Leuphana University of Lueneburg, weisenfeld@uni.leuphana.de
[b]Institute for the World Economy (IfW), Kiel,
and Hamburg Institute of International Economics (HWWI), Hamburg

September 14, 2009

Abstract

We analyze students' knowledge and risk perception of four technologies. The aim is to find out whether there is a relationship between area of study (self-selection) and progress of study (socialization) on the one hand and risk perception of technologies regarding health, environment and society on the other. The four technology fields under study are renewable energies, genetic engineering, nanotechnology and information and communication technologies (ICT). Key results are: Irrespective of study area, study progress and gender, genetic engineering has the highest perceived risk and renewable energies has the lowest. This holds for all the risks studied (environmental, health, societal risks). For most risk perception variables, advanced students perceive lower risks than beginners, and students in a technical study area perceive lower risks than students in a non-technical area. Factor analyses show that common dimensions of risk are the technological areas and not the type of risk. Regression analyses show that the variables influencing perceived risks vary between the technological fields.

Keywords: technologies, risk perception, self-selection, socialization

JEL-code: O33

Acknowledgements: We would like to thank participants of the 2009 S.NET conference in Seattle as well as participants of the research seminar the TU Hamburg Harburg for valuable comments.

1. Introduction

The pattern of technological development has been the subject of studies with different emphases, ranging from niche formation (Kemp et al. 1998) to multi-level perspective on transition (Geels and Schot 2007). This article focuses on antecedents of potential actors' and stakeholders' behaviour by analyzing the effects of *self-selection* and *socialization* on the *perceived risks* of *new technologies*. New technologies and respective innovations come with chances and risks that are perceived differently by various groups and individuals and are shaped by various actors. Risk perception affects decision making of people involved in activities related to the research, development, introduction, regulation and use of technologies. Therefore, research on risk perception has become increasingly important for the management of technology.

Perceptions of chances and risks, held by various stakeholders (researchers, a company's managers of different functions, customers, 'the public') may differ to a great extent and are subject to many influences. Perceptions usually are based on one's frame of reference and on (incomplete) information. Over time, perceptions and evaluations can change, e.g. on account of additional information (Chatterjee and Eliashberg 1990, Roberts and Urban 1988). Indeed, the expectation that knowledge (relevant information) plays a key role in risk perception has led to numerous studies with mixed results (Schütz et al. 2000) and to initiatives such as the Public Understanding of Science campaign launched by the British government. However, the relationship between knowledge about science and technology on the one hand and respective risk perceptions on the other hand is complex. While Allum et al. (2008) in a meta-analysis across cultures find a small but positive relationship between knowledge and attitude towards technology, they also note that cross-country variation is only 10% which in turn can be accounted for by the percentage of people in tertiary education. In our study we take a closer look at that group: We focus on student groups in Germany.

They all have acquired a certain educational degree (usually 'Abitur' or 'Fachabitur', a prerequisite to enrol at university or polytechnic) that makes them a more homogeneous group regarding knowledge compared to the general public, thereby providing the opportunity to look for other influencing factors on risk perception. Furthermore, in the future, many of today's students will be involved in activities and decisions concerning new technologies. Especially top management positions, engineering and high positions in regulatory institutions are associated with university degrees.

We propose that a typical student choosing a topic in the area of science and technology and a typical student choosing a non-technical subject will differ with regard to their perceptions and attitudes of technologies (self-selection) and that within an area of study, risk perception will be different between beginners and advanced students (socialization). Thus, we differentiate (1) between students in a non-technical area, namely cultural sciences, business administration, and social sciences, and students in a technical area, i.e., engineering and (2) between first term students and students in their third term and above.

Section 2 summarizes key findings in the area of risk perception and section 3 describes self-selection and socialization as potentially important factors in the explanation of attitudes and behaviours. Section 4 gives a short description of the four technologies investigated here. Section 5 presents the empirical study and section 6 draws conclusions.

2 Risk Perception

There is no perfect knowledge about the development and use of technologies. Owing to high complexity, there is a lack of information at any point of time. Different people have different bits of knowledge, leading to asymmetry of information. If one were to collect all the information, things would be already in the process of changing which involves uncertainty. Thus, information asymmetry (varying information about the status quo) and uncertainty (lack of information about the future) lead to risk being an ubiquitous phenomenon.

'Experts' often assess risk as the expected value of the negative outcomes (the harms) of a decision. This process involves judgement (Fischhoff et al. 1978), and thus the results will vary between individuals and across contexts. Information is incomplete and developments are uncertain, hence predictions are based on assumptions. Experts might differ on account of different (scientific) judgement, different reference systems, or their dissent might involve politics. Even if there was a consensus amongst experts: the technical concept of risk is of limited use for policy making (Kasperson et al. 1988), rather, the perception of risk is influenced by other factors next to probabilities and magnitudes of risks.

According to the *psychometric paradigm*, "risk is subjectively defined by individuals who may be influenced by a wide array of psychological, social, institutional and cultural factors" (Slovic 2000, xxiii). Analyses of hazards with different characteristics (*inter-hazard variation*) point to a limited number of risk dimensions such as voluntariness (of taking a risk), controllability and familiarity with risk (Slovic 1987, Renn 1990). Analyses of individuals (*inter-individual variation*) yield mixed results with regard to the relationship between factual knowledge and risk perception. Schütz et al. (2000) assume that next to methodological differences between studies, the type of risk and situational factors may play a role. The *familiarity hypothesis* holds that support for a technology will increase with growing awareness of the technology. For example, support for nanotechnology was positively correlated with the perception that nanotechnology's benefits outweigh its risks, a finding consistent with public opinion studies (Cobb and Macoubrie 2004, Macoubrie 2006). Increasing the knowledge base by providing more information may lead to polarization of views (*cultural cognition*[1]): People tend to base their beliefs about benefits and risks of an activity on their cultural appraisals of these activities (Wildavsky and Dake 1990, DiMaggio 1997). Applied to nanotechnology, Kahan et al. (2009) found that predispositions towards nanotechnology affect information selection and interpretation. Other factors influencing individual risk perceptions are personal experience with the technology and judgement of one's reference group (Renn 1990). Analyses of *socio-demographic variables* show differences in risk perception particularly with regard to gender (Pidgeon 2007)[2]. Thus, the way people develop and express perceptions of risk is determined by individual, social, cultural and situational factors. In conclusion, risk perception is a complex construct and there is a whole range of variables that may explain some part of variance.

In our study we look at four technologies that differ regarding familiarity and the degree of public discussions being controversial. We analyse individuals who differ regarding their values and science orientation (self-selection, socialization). Finally, we take gender as the important socio-demographic variable into account.

3 Self-Selection and Socialization

Self-selection refers to individuals selecting themselves into a group. For self-selection to happen there has to be a choice between alternative options such as between jobs or between study areas. *Socialization* refers to the process by which values, attitudes and practices of individuals are brought into line with those of the group they belong to.

Already when enrolling in university and selecting a subject, students of various disciplines display significant differences regarding values: "Students choose a subject the disciplinary culture of which has an affinity to their own values and norms or,

[1] "Cultural cognition refers to the tendency of individuals to conform their beliefs about disputed matters of fact (e.g., whether global warming is a serious threat; whether the death penalty deters murder; whether gun control makes society more safe or less) to values that define their cultural identities." http://culturalcognition.net/, accessed 15.06.09

[2] Other variables are e.g., income and race; Flynn et al (1994) call the combined effect of race and gender the 'White male effect'.

alternatively, reject subjects with an image that stands in contrast to their own orientations" (Windolf 1995, 225). Unlike the USA, UK or France, Germany still has a relatively homogeneous university sector (Windolf 1995, 208). Even if this is about to change (Deutschland magazine 2008), so far a key determinant for enrolment in a university is the subject studied. Choosing a subject to study (self-selection), be it sciences, engineering, business, culture or social relations, is associated with cognitive orientations, values and norms. Students enrolling in different subjects differ regarding career expectations, cognitive abilities, preferred lifestyle and with respect to their attitude towards science (Zarkisson and Ekehammar 1998). This attitude may vary over time.

During their studies, students do not only acquire specialized knowledge but are also exposed to the standards, supervision and peer culture of their disciplines amongst which are considerable differences (Weidman et al. 2001). That disciplinary culture as a 'code of ethics' is important for the production, acquisition and use of knowledge (Windolf 1995, 210).

Trautwein and Lüdtke (2007) analyzed the relationship between study field chosen and students' epistemological beliefs for beginners (self-selection) and for advanced students (socialization). The results indicate that both self-selection and socialization are at work in the context of attitudes towards science: Certainty scores, i.e. high scores indicating the belief that scientific knowledge is certain and not subject to change, were lower for 'soft' disciplines like humanities, arts, and social sciences and decreased with time. Risks are matters of social conflict, and the definition of 'the problem' provides legitimacy (Dietz et al. 1989) for positions (pro or against a technology) and actions (promoting research or destroying genetically modified (GM) plots). The *social identity approach* posits that people adopt attitudes and beliefs typical for their group as their own (Wood 2000, 557). Socialization then contributes to the development of perceptions and goals which are of course key to actions and strategies of people in various positions. Thus, self-selection and socialization are potentially important factors in the explanation of attitudes and behaviours and the understanding of risk perception.

4 Technologies

New technologies are associated with benefits and risks. Fierce debates about for example nuclear energy or GM crops and food show that in many societies, 'the public' does not welcome technologies without reservation but demands debates on their implications and potential hazards (Frewer 2003). Some technologies are more controversial which means there is an ongoing discussion about its risks, while others are less controversial where the perceived advantages clearly dominate perceived risks. With technologies (as opposed to 'nature') creating environments and new risks, the associated increased complexity and uncertainty makes technological developments less and less predictable and manageable: According to Beck (1986) we live in a risk society.

In what follows we sketch some of the opportunities and threats associated with those technologies considered in our survey, namely renewable energies, nanotechnologies, ICT, and genetic engineering. These technologies are part of the so-called high technologies sector. They are key change drivers and possible convergence of high technologies such as nanotechnology, modern biology, and ICT "will bring about tremendous improvements in transformative tools, generate new products and services, enable opportunities to meet and enhance human potential and social achievements, and in time reshape societal relationships" (Roco 2007). As detailed below, the four technologies discussed here differ regarding people's knowledge, expectations, and concerns associated with the technologies.

Modern Biotechnologies, Nanotechnologies and ICT are categorized as general purpose technologies (Sheehan et al. 2006, Ruttun 2007) which include (i) pervasiveness, i.e.

they may be used in a large number of industries, (ii) innovation spawning, i.e. the technology leads to innovations in application sectors, (iii) complementarities in the sense that innovation processes between upstream and downstream sectors are linked (Bresnahan and Trajtenberg 1995, Helpman 1998). Referring to the reorganization of work-life processes, Lipsey et al. (1998) highlight the societal implications of general purpose technologies.[3]

The term *renewable energies* covers forms of energy generated from resources that are naturally replenished such as sunlight, wind, water, or geothermal heat. Non-renewable energies are naturally scarce and are associated with huge environmental burden. Lower dependency on foreign energy sources, greening of industries and increasing public environmental awareness are key drivers for the development and diffusion of renewable energies (Greenwood et al. 2007). However, the materials, industrial processes, and construction equipment used to create them may generate waste and pollution. Thus, some renewable energy systems may create environmental problems. Nevertheless, renewable energies are perceived as strongly contributing to resolving environmental problems and securing energy supply. Risks are mostly discussed in the context of investment failure (UNEP 2006) which could hamper further development of the technology: “the risk profiles of renewable technologies differ significantly from those of fossil fuel and nuclear plants. In particular, use of renewable energy options generally pose little or no environmental, fuel price or security risks” (Rickersen et al. 2005, 47).

All in all, renewable energies have a positive image, there are hardly any risks perceived but significant benefits.

---

[3] Examples are e.g. the societal impact of electricity: For the first time this made people independent from daylight which to restructuring of production processes, allowed for shift work and hence also impacted on daily routines of entire families (Lipsey et al. 1998). Another example: The ongoing penetration of ICT allows for ‘mobile’ offices thereby also leading to a restructuring of business routines which in the end also spill over beyond professional activities.

ICT covers technologies for the generation, transmission, storage and manipulation of information and communication. During the last decades the wide-spread diffusion of ICT and its rapid further development had a great impact on societies and ICT are still major drivers of economic and social change, however, "Industry's goal of digital content "anywhere, anytime and on any device" is still remote" (OECD 2008). The implementation of ICT also plays a major role in the shift towards knowledge-based societies, but "as the digital access divide decreases a digital use divide is emerging" (OECD 2008).

So far the risks inherent in ICT as perceived by the public are not very extent. Most objections refer to societal risks such as loss of control, technological dependence or surveillance associated with 'smart objects'. In sum, ICT have mainly a positive image, there are some societal risks associated with them.

Genetic engineering "refers to the process of inserting new genetic information into existing cells for the purpose of modifying one of the characteristics of an organism" (United Nations 1997). It plays a key role in many areas such as agriculture, food, medicine, and chemical industry. While many actors and institutions support its developments, others oppose it fiercely. Worldwide, albeit to a different degree, it has been debated very controversially. The issues cover economical, ethical, health and social concerns.

The application of genetic engineering to the agro-food sector and the health sector is a prominent example of the importance and complexity of stakeholder issues. While medical applications are favorably, even uncritically, judged (TAB 2002), genetically modified food is seen as not necessary or even as being dangerous. However, the knowledge about genetic engineering can be described as vague, with little connection between bits of knowledge (Eurobarometer, Pfister et al. 2000). Genetic engineering is controversially discussed; risks are perceived with regard to health, the environment and society (e.g. human enhancement).

The term *nanotechnologies* covers technologies and devices working at an atomic and molecular scale (dimensions smaller than 100 nanometers). The manipulation of nanostructures allows for ongoing miniaturization, leads to using newly discovered properties of materials and provides multiple possibilities in animate and inanimate contexts. Nanotechnologies form part of technological platforms (Robinson et al. 2006). While genetic engineering is based on the 'code of life', Nanotechnologies are concerned with molecular structures. Thus, both technological fields really are at the centre of 'things' and are general purpose technologies. They differ with regard to the public awareness: Genetic engineering has been discussed for more than three decades, whereas nanotechnologies are hardly known by the public (Kahan et al. 2009). Nanotechnologies are discussed controversially; however, so far, most people are not familiar with the technologies.

5. Empirical Study

5.1 Context of the Study and Propositions

In 2005 the European Commission published the results of an empirical study on Europeans, Science and Technology. Citizens from 25 European countries were asked about their knowledge (including a knowledge quiz), interests and perceptions regarding science and technologies. Aiming at a representative study of citizens of 15 years of age and over (Eurobarometer 224, 2005, 130) and assessing variables such as age, gender, education and occupation, results for a number of socio-demographic groups are available. The report concludes that "Europeans consider themselves poorly informed on issues concerning science and technology" and that "the gap between science and society still exists. Efforts must namely be made in order to bring science and technology closer to certain categories of people who are less exposed to the scientific field, and who therefore have a more sceptic perception of science and technology" (Eurobarometer 224, 2005, 125). However, detailed analyses of specific population groups are not carried out.

Such an investigation of special groups has been performed by Lüthje (2008): differentiating between people with a technical and an economic background, Lüthje asked engineering and business administration students (beginners and advanced students) and professionals (engineers and managers) about various aspects of cooperation (amongst others: task preferences, information style, risk attitude in innovation projects, goal orientation and time preferences). With regard to risk attitude in innovation projects[4] there are no significant differences between engineering and business student beginners, but in the group of advanced students and in the group of professionals, (prospective) engineers display a lower preference for (financial) risks than (prospective) managers. However, risk has been limited to financial risk of innovation projects. Trautwein and Lüdtke (2007) analyzed the relationship between study field chosen and students' epistemological beliefs and identified effects of both self-selection and socialization.

In our study we analyze German students' risk perception of four technologies. The students differ regarding their major study area (‚tech' and ‚non-tech': self-selection) and regarding the study progress ‚beginners' and ‚advanced': socialization). The four technology fields under study are renewable energies, genetic engineering, nanotechnology and ICT.

We propose that

Proposition 1: Self-Selection

[4] Assessed through three items, e.g. "I prefer projects with relatively low risk (and moderate, but certain profit)".

Students who choose a technical field perceive lower health, environmental and societal risks than students who choose a non-technical field.

Proposition 2: Socialization

(a) Advanced students in a technical field perceive lower health, environmental and societal risks than beginners in a technical field

(b) Advanced students in a non-technical field perceive higher health, environmental and societal risks than beginners in a non-technical field

Proposition 3: Inter-technology variation

The effects of self-selection and socialization will hold for all the four technologies and for all types of risks investigated here.

5.2 Data

Sample

In our study we analyze German students' risk perception of four technologies. The students differ regarding their major study area in technical and non-technical fields thereby also reflecting some kind of self-selection. Socialization comes into play since we also distinguish between beginners and advanced students the latter referring to 3rd term students and above. The four technologies under study are renewable energies, genetic engineering, nanotechnology and ICT and we distinguish for each technology the fields health, society and environment.

The total sample consists of 1400 questionnaires (owing to missing values, the number of answers varies slightly with the questions). We collected the data within three months (December 2007 to February 2008), from three North German universities (Lüneburg, Hamburg and Flensburg). The non-technical study areas include Cultural

Studies, Education (teaching), Social Sciences, Business Studies, and Economics. In the following students in these field will be denoted as ‘non-tech’. The technical study fields covered engineering: general, construction, water, ship building, and we denote those students ‘tech’. Table 1 gives an overview over the sample.

Table 1 about here

Knowledge and Familiarity with the Technologies

Are people overconfident, i.e., do they think they are more knowledgeable than they actually are?[5] In the context of risk perception, overconfidence may lead to an overly optimistic or pessimistic view on a technology. For example, being familiar with renewable energies on account of reports in the media that it is a desirable approach to energy generation may lead to people thinking that they know a fair amount about the technologies involved and attributing low risk to the respective technologies. Similarly, being aware of the controversial discussions around genetic engineering may lead to attributing high risk to the technology.

We distinguished between two types of knowledge: Participants were asked to indicate how well they are informed about the four technologies (‘familiarity’ – or self-assessed knowledge, Table 2) and they completed a knowledge quiz (factual knowledge, Table 3). Note that correlation analysis shows highly significant correlations between knowledge (both self-assessed and factual) about science and technology and the choice of any field of study: Those students choosing a technical field also dispose of more knowledge on technological topics.

[5] Alba and Hutchinson (2000, 123) analyze that proposition with respect to consumers: “Are consumers overconfident?”.

Table 2 about here

Respondents seem to be more familiar with ICT and renewable energies and less familiar with genetic engineering and particularly with nanotechnologies. It is remarkable that the most common rating of familiarity with nanotechnologies is 1, that is 296 respondents (21%) indicated that they are not at all informed. Nanotechnologies and particularly genetic engineering are also seen more controversially.

Out of the four technologies, nanotechnology is the least understood technology, genetic engineering is the most controversial technology, respondents indicate higher familiarity with ICT and renewable energies and the latter is seen as least risky.

Table 3 about here

Four questions of the knowledge quiz (2, 3, 4, 5: Tab. 3) were adapted from the Eurobarometer (2005), and four additional questions related to the four technologies investigated here. The highest percentage of right answers is given for the question on radioactivity (4), followed by the question on genetic engineering (1). Radioactivity and genetic engineering are issues that have been discussed intensely in the media. The lowest percentage of right answers is given for the question on nanotechnology (7). This corresponds well with the self-assessed knowledge where nanotechnology also ranks last. Compared with the Eurobarometer 2005 (see last column of Table 3) the percentage of right answers is for all four questions higher in this survey.[6] Both

[6] However, in the three years between the Eurobarometer survey and our survey, discussion went on and the respondents in our survey may have taken notice of these discussions.

familiarity ratings and knowledge scores vary with gender, study field and study progress (Table 4).

Table 4 about here

The average knowledge scores (last column of Table 4) are higher for students in a technical field than in a non-technical field. The same holds for the mean ratings of familiarity with regard to renewable energies and nanotechnologies. A Mann-Whitney-U-Test[7] reveals that these differences between students in a technical and in a non-technical field are significant. This is not true for genetic engineering. In conclusion, the groups in different study areas investigated here show significant differences regarding their knowledge scores and their familiarity with technologies except for genetic engineering.

Risk perception of the technologies

For each technology, the respondents were asked to rate the health risk, environmental risk and the societal risk as follows (example here: type of risk = health risks and technology = genetic engineering):

> I rate the health risks of genetic engineering as … 1-no risk at all to 11- very high risk

Table 5 reports the mean ratings of *health risks* for the total sample and by gender, study field and study progress.

Table 5 about here

[7] The Mann-Whitney-U-Test is a non-parametric test for assessing whether two independent samples of observations come from the same distribution.

For each technology, i.e., in each column (in bold), the highest average group rating is in a female group and the lowest average group rating is in a male group. For every group, i.e., in each row, renewable energies has the lowest rating and genetic engineering has the highest. Thus, in the sample is consensus about which is the least risky and which is the most risky technology.

Risk perception and self-selection

Proposition 1 states that students in a technical area perceive risks to be lower. Since the majority of students in the technical area is male and gender is important in risk perception, each gender group is analyzed separately.[8] Figure 1 shows the mean ratings for female students in the technical (N = 100) and non-technical (N = 645) study area.

Figure 1 about here

There are no significant differences in risk perceptions between the two female groups with regard to highly controversial genetic engineering and the 'no risk' renewable energies. However the differences in mean ratings are significant ($p<0,05$) for the risks associated with nanotechnologies (all types: health, environment and society) and for perceived societal risks of ICT: non-technical female students perceive those risks to be higher than technical female students.

Figure 2 shows the mean ratings for male students in the technical (N = 356) and non-technical (N = 207) study area.

[8] Most of the variables are not normally distributed (Kolmogorov-Smirnov test), therefore the Mann-Whitney-U test was used to assess differences in ratings.

Figure 2 about here

The differences between the two male groups are significant ($p<0,05$) for both the risks associated with nanotechnologies and for genetic engineering (all types: health, environment and society): non-technical male students perceive those risks to be higher than technical male students.

Thus, students selecting themselves into a technical versus non-technical study area, differ in their risk perception of two out of the four technologies analyzed here.

Proposition 1:

Students who choose a technical field perceive lower health, environmental and societal risks than students who choose a non-technical field,

is supported for those technologies for which significant differences in risk perceptions exist. Put differently, if risk perceptions differ significantly between tech and non-tech groups, it is the non-tech group that perceives risks to be higher. This result holds for both male and female students.

Risk perception and socialization

Proposition 2 refers here to the development of attitudes and perceptions during students' studies. Depending on their study area, risk perceptions are expected to increase (non-technical area) or decrease (technical area), that is, pre-existing perceptions will be amplified as a consequence of socialization. Hence we expect first-term students in a technical field to display higher risk perceptions than advanced students in a technical field: During their studies students become more familiar with the technical side of technologies, they identify themselves with their study subject and adopt attitudes and beliefs typical for their group as their own. With the same reasoning, we expect first-term students in a non-technical field to display lower risk perceptions than advanced students in a non-technical field. Students in the area of cultural and societal studies get more exposed to the non-technical side of technology including topics such as stakeholders' positions and society's acceptance. Following the logic of the cultural cognition hypothesis we thus expect that any initially existing risk perception to be amplified as a consequence of socialization. We therefore compare for technical students the mean rating of the two groups 'beginners' and 'advanced' (see Figure 3) and do the same for students in non-technical fields of study (see Figure 4).

Figure 3 about here

Fig. 3 shows that in a technical area beginners rate risks higher than advanced students; the differences between mean ranks (Mann-Whitney-U test) are significant for nanotechnologies (health, environment, society), ICT (health, environment, society) and genetic engineering (society).

Proposition 2 (a)

Advanced students in a technical field perceive lower health, environmental and societal risks than beginners in a technical field,

is supported for those technologies for which significant differences in risk perceptions exist: if risk perceptions differ significantly between beginners and advanced students, it is the beginner group that perceives risks to be higher.

Figure 4 about here

In the non-technical area, beginners rate risks higher than advanced students; the differences between mean ranks (Mann-Whitney-U test) are significant for all risk perception variables except for renewable energies (health, environment, society) and nanotechnologies (health).

Proposition 2 (b)

Advanced students in a non-technical field perceive higher health, environmental and societal risks than beginners in a non-technical field,

is not supported; if risk perceptions differ significantly between beginners and advanced students, it is again the beginner group that perceives risks to be higher.

In conclusion, study progress is associated with lower risk perceptions, regardless of the study area (technical or non-technical).

The results so far also show that Proposition 3

The effects of self-selection and socialization will hold for all the four technologies and for all types of risks investigated here,

is not supported: The effects of self-selection and socialization do not hold for all the four technologies.

5.3 Relationship between risk perception, study area and study progress

Dimensions of risk perception

As discussed above, the mean ratings are highest for genetic engineering and lowest for renewable energies. This holds for all the risks studied (environmental, health, societal risks). Indeed, a factor analysis of risk perception variables shows that it is the technological areas and not the types of risk that are the relevant dimensions of risk perception (Table 6).

Table 6 about here

The factor loadings are based on the twelve questions on risk perception of four technologies regarding the three areas environment, health and society. The grouping of the high factor loadings leads to the four factors (i) ‘Risks associated with renewable energies’: RiskRenE, (ii) ‘Risks associated with nanotechnologies’: RiskNano, (iii) ‘Risks associated with ICT’: RiskICT and (iv) ‘Risks associated with genetic engineering’: RiskGenE.

Regression analyses

Specifying each factor from the factor analysis as a dependent variable, and study area and study progress as independent variables, regression analyses show the relationship between these variables (Table 7):

$$\text{Risk perception (technology)} = \text{constant} + b_1 \cdot \text{study area} + b_2 \cdot \text{study progress}.$$

Analyses were performed for male and female respondents separately. Significant results are in bold numbers.

Table 7 about here

The regression analyses show no significant results for risk perceptions concerning renewable energies. Concerning risk perception of nanotechnologies, the selection variable (study area) is significant for both male and female students, indicating that students in a technical area perceive lower risks than students in a non-technical area. Study progress is only significant for female students with advanced students perceiving lower risks. With respect to risk perception of genetic engineering, the selection variable is significant only for male students, that is, male students in a technical field perceive lower risks than male students in a non-technical field. In contrast to that, study progress is significant only for female students: female advanced students perceive lower risks than female beginners. With regard to ICT, both female and male advanced students perceive lower risks than beginners.

6 Discussion

As illustrated above, the relationship between self-selection and socialization on the one hand and risk perception of technologies on the other varies between technologies. The results presented show that there is consensus amongst the groups about renewable energies posing hardly any risk and genetic engineering being the most risky technology of the four technologies investigated here. However, there are differences regarding the level of risk perception.

Renewable energies have a positive image, people indicate a relatively high degree of familiarity, there are hardly any risks perceived; this holds for all groups analyzed here. There are no significant differences in risk perception between different study areas or with regard to study progress.

As shown in Table 2, *nanotechnology* is the least understood technology with a median familiarity ranking of 3. However, it is also the technology for which the range of average familiarity rating between female first year students in a non-technical area (2,64) and male advanced students in a technical area (5,54) is greatest (see Table 4). In this case, higher familiarity goes with lower risk perception. *Genetic engineering* is the most controversial technology and for all but one group, familiarity is rated as high as or higher than nanotechnologies. Since genetic engineering is not part of the technical study areas investigated here, it is neither a particular interest in that technology, nor a growing familiarity owing to studying the topic that could account for differences in familiarity. Rather, it might be the exposure to discussions in the media that lead to respondents indicating similar levels of familiarity. Gender plays an important role: For male students, risk perception differs between technical and non-technical areas; however, this is not the case for female students. With regard to *ICT*, in both the technical and the non-technical area advanced students perceive lower risk than beginners. ICT is a general purpose technology that is wide-spread and many people are accustomed to using it on a daily basis. Performing studies at university usually comes with intense usage of ICT which might put risks into a different perspective.

The results of this study suggest that selection and socialization effects on risk perception vary between technologies: For non-controversial technologies, risk perception is homogeneous. For controversial technologies with affinity to an area of study, students in that area perceive lower risks than students in other areas, even as beginners. For controversial technologies with no affinity to an area of study, gender plays an important role.

7 Conclusion

Pupils are taught every day systematically, i.e., according to a specified, often nation-wide schedule. In its report ‚Rising above the gathering storm: Energizing and employing America for a brighter economic future‘(National Academies of the USA 2005), the first recommendation is to "increase America's talent pool by vastly improving K-12 science and mathematics education" (p. 5). However, the relationship between knowledge and technological development is not straightforward: Participating in the creation of technological paths, people's intentions, strategies and actions are partly influenced by how chances and risks of the technology are perceived: Risk perception plays a crucial role in technology development. It is not only "science and mathematics" but equally an understanding of risks and chances and the way perceptions develop that could "bring science and technology closer to certain categories of people who are less exposed to the scientific field, and who therefore have a more skeptic perception of science and technology" (Eurobarometer 224, 2005, 125).

Students select themselves into an ongoing learning process and choose a field of study. This self-selection partly will reflect attitudes towards science, preferences for topics and career expectations. Going to university, the teaching and learning of subjects become less uniform. Each discipline has its own culture and its ways for producing and using knowledge. Socialization processes may contribute to the development of 'typical' perceptions.

In an organization people take on roles and tasks: a financial controller, a researcher and a marketing manager differ in their screening and evaluation of innovations and in their level and type of information. In general, scientists and developers may be better informed about technical aspects, marketing managers may be better informed about user needs and usage patterns. Homophily (Lazarsfeld and Merton 1954) between members of a group (or a department in an organization) may strengthen attitudes and confirm perceptions. This may affect intra-organizational interaction between managers of different departments as well as inter-organizational interaction. For example, Kim and Higgins (2007, 510) propose that "the prominence of members' prior careers influenced the rate at which companies form alliances".

It is this kind of knowledge about selection and socialization processes that could further the *understanding* of cooperation partners' perceptions as well as differences in perceptions.

References

Alba, J.W., Hutchinson, J.W. 2000. Knowledge calibration: What consumers know and what they think they know, Journal of Consumer Research 27, 123-156.

Allum, N., Sturgis, P., Tabourazi, D., Brunton-Smith, I. 2008. Science knowledge and attitudes across cultures: A meta-analysis, Public Understanding of Science 17 (1), 35-54.

Beck, U. 1986. Risikogesellschaft. Auf dem Weg in eine andere Moderne. Frankfurt a.M.

Bresnahan, T., Trajtenberg, M. 1995. General purpose technologies: Engines of growth, Journal of Econometrics, 65, 83-108.

Chatterjee, R., Eliashberg, J. 1990. The innovation diffusion process in a heterogeneous population: A micromodeling approach, Management Science 36(9), 1057–1079.

Cobb, M.D., J. Macoubrie 2004. Public perceptions about nanotechnology: Risks, benefits and trust, Journal of Nanoparticle Research, 6, 395-404.

Deutschland magazine (2008), The best universities, http://www.auswaertiges-amt.de/diplo/en/WillkommeninD/LernenUndArbeiten/Studium/Eliteunis.html, updated 28.01.2008.

Dietz, T., Stern, P.C., Rycroft, R.W. 1989. Definitions of conflict and the legitimation of resources: The case of environmental risk, Sociological Forum 4 (1) 47-70.

DiMaggio, P. (1997), Culture and cognition, Annual Review of Sociology, 23, 263-287.

Eurobarometer 224 (2005): Europeans, Science and Technology, http://ec.europa.eu/public_opinion/archives/ebs/ebs_224_report_en.pdf .

Fischhoff B, Slovic P, Lichtenstein S, Read S, Combs B 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Science 9 (2) 127–152.

Frewer L (2003), Societal issues and public attitudes towards genetically modified foods. Trends in Food, Science and Technology 14, 319–332.

Flynn, J., Slovic, P., Mertz, C.K. 1994. Gender, race and perception of environmental health risks. Risk Analysis 14 (6) 1101 - 1108.

Geels, F.W. and Schot, J.W. 2007. Typology of sociotechnical transition pathways. Research Policy 36 (3) 399-417.

Greenwood, C., Hohler, A., Hunt, G., Liebreich, M., Sonntag-O'Brien, V., Usher, E. 2007. Global trends in sustainable energy investment. United Nations Environment Programme and New Energy Finance Ltd. 2007.

Helpman, E. 1998. General purpose technologies and economic growth, Cambridge.

Kahan, M., Braman, D., Slovic, P., Gastil, J., Cohen, G. 2009. Cultural Cognition of the risks and benefits of nanotechnology. nature nanotechnology 4, 87-90.

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., Ratick, S. 1988. The social amplification of risk: A conceptual framework. Risk Analysis 8 (2), 177-188.

Kemp, R., Schot, J. Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation. The approach of strategic niche management. Technology Analysis and Strategic Management 10 (2), 175-195.

Kim, J. W., Higgins, M. C. 2007. Where do alliances come from? The effects of upper echelons on alliance formation. Research Policy 36 (4), 499-514.

Lazarsfeld, P. F., Merton, R. K. (1954). Friendship as a social process: A substantive and methodological analysis. In Berger, M., Abel, T., Page, C. (Eds.), Freedom and Control in Modern Society, 18-66, New York: Van Nostrand.

Lipsey, R., Bekar, C., Carlaw, K. 1998. What requires explanation? In General purpose technologies and economic growth, ed. Helpman, E., 55-83. Cambridge.

Lüthje, C. 2008. Der Prozess der Innovation. Das Zusammenwirken von technischen und ökonomischen Akteuren, Tübingen: Mohr Siebeck.

Macoubrie, J. 2006. Nanotechnology: Public concerns, reasoning and trust in government, Public Understanding of Science 15, 221-241.

National Academies of the USA 2005: Rising above the gathering storm: Energizing and employing America for a brighter economic future.

OECD (2008): OECD Information Technology Outlook 2008 Highlights, http://www.oecd.org/dataoecd/37/26/41895578.pdf .

Pfister, H.-R., Böhm, G., Jungermann, H. 2000. The cognitive representation of genetic engineering: Knowledge and evaluations. New Genetics and Society 19, 295-316.

Pidgeon, N. 2007. Gender theories and risk perception: A secondary analysis: Full Research Report, ESRC End of Award Report, RES-160-25-0046. Swindon: ESRC.

Renn, O. 1990. Risk perception and risk management. Risk abstracts, Institute for Risk research, university of Waterloo, Ontario, 1-9.

Rickerson, W., Wong,H., Byrne,J., Young-Doo Wang, Sasser, S. 2005. Bracing for an uncertain energy future: Renewable energy and the US electricity industry. Risk Management Matters 3 (1), 46-61.

Roberts, J. H., Urban, G.L.. 1988. Modeling multiattribute utility, risk, and belief dynamics for new consumer durable brand choice. Management Science 34, 167–185.

Robinson, D.K, Rip, A., Mangematin, V. 2006. Technological agglomeration and the emergence of clusters and networks in nanotechnology (Working paper GAEL 2006-5). Grenoble, France: Université Pierre Mendès France.

Roco, M.C. 2007. Governance of converging new technologies integrated from the nanoscale, Keynote at PICMET 2007. http://www.picmet.org/new/Conferences/2007/keynotes.aspx#Roco .

United Nations 1997. Glossary of environment statistics, Studies in Methods, Series F, No. 67, New York.

Ruttan, V.W. 2007. General purpose technology, revolutionary technology, and technological maturity, Draft, http://www.apec.umn.edu/documents/VRuttanApEcSemSp07.pdf .

Schütz, H., Wiedemann, P.M., Gray, P.C.R. 2000. Risk perception and beyond the psychometric paradigm (Heft 78). Jülich, Germany: German Research Centre Jülich, Programme Group Human Environment Technology.

Slovic, P. 1987. Perception of risk, Science 236, 280-285.

Slovic, P. 2000. Introduction and overview, in: Slovic, P. The perception of risk, London.

Sheehan, P., Houghton, J., Rasmussen, B., Sweeny, K., Tegart, G. 2006. Consistent national policies for converging technologies: Some preliminary conclusions. Policy Report of the CSES project General purpose technologies, complementarities and the convergence of industries, Australian Research Council ARC Linkage Grant Project ID: LP0349387, http://www.businessandlaw.vu.edu.au/cses/documents/research_reports/2006_CSES_GPT_Final_Report.pdf .

TAB 2002. Technology acceptance and controversies over technology: Positive changes in the state of opinion – consistent attitude patterns, TAB working report No. 83, http://www.tab.fzk.de/en/projekt/zusammenfassung/ab83.htm .

Trautwein, U., Lüdtke, O. 2007. Epistemological beliefs, school achievement, and college major: A large-scale longitudinal study on the impact of certainty beliefs, Contemporary Educational Psychology 32, 348-366.

UNEP 2006. Financial risk management instruments for RE projects.

Weidman, J.C., Twale, D.J., Stein, E.L. 2001. Socialization of graduate and professional students in higher education: A perilous passage? ASHE-ERIC Higher Education Report 28 (4), San Francisco.

Wildavsky, A. Dake, K. 1990. Theories of risk perception: Who fears what and why? Deadalus, 114, 41-60.

Windolf, P. 1995. Selection and self-selection at German mass universities, Oxford Review of Education 21 (2), 207-231.

Wood, W. 2000. Attitude change: persuasion and social influence, Annu. Rev. Psychol. 51, 539-570.

Zarkisson, I., Ekehammar, B. 1998. Social attitudes and education: Self-selection or socialization? Scandinavian Journal of Psychology 39, 117-122.

Table 1: Overview of Sample, N=1400

Variable		Valid %
Sex	Female	57.3
	Male	42.7
Age	≤ 20	33.5
	21-25	52.6
	26-30	8.2
	> 30	4.7
Field of studies	‚Non-Tech‘	65.8
	‚Tech‘	34.2
Study progress	Beginners	79.2
	Advanced	20.8

Table 2: Familiarity with Technologies: Ratings

I am informed about … renewable energies … as follows				
	renewable energies	ICT	genetic engineering	nano technologies
Mean	6.39	6.05	5.27	3.69
Median	7	6	5	3
Modus	8	6	4	1
SD	2.26	2.46	2.19	2.33
N	1399	1399	1398	1398

Scale: 1 = not at all informed, 11 = very well informed

Table 3: Quiz results: factual knowledge

	% Don't know	% wrong answer	% right answer	% right answer EU 2005
1 Naturally, tomatoes have genes	9.2	10.8	80.0	n.a.
2 Lasers work by focusing sound waves.	28.4	13.9	57.7	47
3 Antibiotics kill viruses as well as bacteria	11.4	21.3	67.2	46
4 Radioactive milk can be made safe by boiling it	14.1	0.7	85.3	75
5 Electrons are smaller than atoms.	10.4	21.3	68.2	46
6 For a certain irradiation angle of the sun, the power generation of a photovoltaic power plant will be higher in the summer than in the winter	35.6	27.9	36.5	n.a
7 With the scanning tunneling microscope it is possible to move single atoms	63.7	26.0	10.3	n.a.
8 With respect to speed fiberglass technology is superior to copper	35.4	6.0	58.5	n.a

Table 4: Familiarity and knowledge by study area, study progress and gender: Mean ratings (1-11) and scores (0-8)

	Familiarity (1-11)				Quiz
Group (N)	RenEn	GenEng	Nano	ICT	Score (0-8)
NonTechBeginnersF (520)	5.69	5.42	2.64	5.35	3.75
NonTechAdvancedF (76)	5.48	4.51	3.08	6.13	3.68
NonTechBeginnersM (143)	6.80	5.48	3.93	6.74	4.70
NonTechAdvancedM (35)	6.46	5.20	4.03	6.89	4.89
TechBeginnersF (74)	7.20	6.01	4.24	5.66	5.31
TechAdvancedF (26)	7.23	5.00	4.85	5.58	5.92
TechBeginnersM (240)	7.30	5.13	5.13	6.82	5.94
TechAdvancedM (114)	7.86	5.17	5.54	6.91	6.04
Total (1228)	6.46	5.31	3.75	6.06	4.67

RenEn=renewable energies, GenEng=genetic engineering, Nano=nanotechnologies, ICT=Information & Communication Technologies

Study area: non-technical field (NonTech), technical field (Tech)

Study progress: first-term (Beginners), third-term and above (Advanced)

Gender: female (F), male (M)

Table 5: Mean ratings of health risks by study area, study progress and gender

		I rate the … health risks … as follows			
		renewable energies	genetic engineering	nano-technologies	ICT
Non-tech BeginnersFf.	Mean	**3.02**	7.43	**5.93**	4.76
	N	508	512	477	503
Non-tech AdvancedF.	Mean	2.87	6.88	5.53	4.11
	N	76	76	74	76
Non-tech BeginnersM.	Mean	2.71	7.21	5.27	4.82
	N	142	142	139	141
Non-tech AdvancedM.	Mean	2.51	6.97	5.26	3.89
	N	35	35	35	35
Tech BeginnersF.	Mean	2.87	**7.57**	5.49	**5.11**
	N	74	74	74	74
Tech AdvancedF.	Mean	2.46	6.31	4.19	3.73
	N	26	26	26	26
Tech BeginnersM.	Mean	2.50	**6.29**	4.46	4.35
	N	240	239	235	238
Tech AdvancedM.	Mean	**2.43**	6.40	**3.90**	**3.61**
	N	113	113	114	113
total	Mean	**2.78**	**7,02**	**5,25**	**4,51**
N	N	1214	1217	1174	1206

1-no risk at all … 11 very high risk

Study area: non-technical field (NonTech), technical field (Tech)

Study progress: first-term (Beginners), third-term and above (Advanced)

Gender: female (F), male (M)

Table 6: Risk Perception for four technologies in three areas: factor loadings

	Factor			
	I RiskRenE	II RiskNano	III RiskGen	IV RiskICT
Health Risks				
RenEn	0.**848**	0.113	-0.006	0.058
GenEng	0.027	0.195	0.**860**	0.060
Nano	0.095	0.**816**	0.242	0.082
ICT	0.091	0.036	0.152	0.**816**
Environm. Risks				
RenEn	0.**861**	0.032	0.056	0.036
GenEng.	0.000	0.154	0.**814**	0.166
Nano	0.088	0.**792**	0.252	0.178
ICT	0.025	0.208	0.127	0.**753**
Societal Risks				
RenEn	0.**834**	0.097	-0.003	0.035
GenEn	0.020	0.280	0.**663**	0.182
Nano	0.101	**0.809**	0.158	0.222
ICT	0.015	0.167	0.085	**0.696**

RenEn=renewable energies, GenEng=genetic engineering, Nano=nanotechnologies, ICT=Information & Communication Technologies

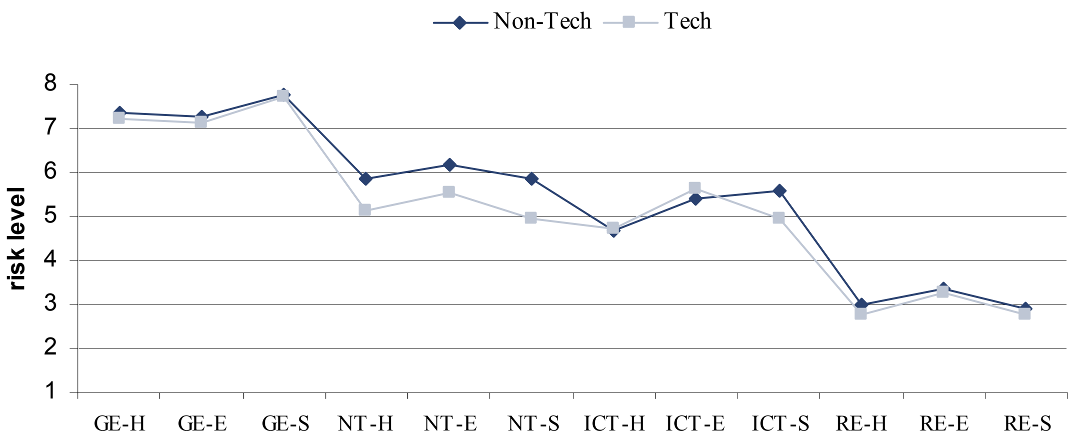
I – Risk renewable energies (RiskRenE), II- Risk nanotechnologies (RiskNano), III – Risk genetic engineering (RiskGenE), IV – Risk ICT (RiskICT)

Table 7: Regression Analyses:

Risk Perception = const. + b1 (selection) + b2 (study progress)

Technology (factor values)	Sample, N	constant (significance level)	b1 selection 1 = tech	b2 study progress 1 = beginners	R, R2
RiskRenE	**All**	-0.011	-0.072	0.062	0.047, 0.002
	1165	(0.874)	(0.241)	(0.398)	(0.278)
	Male	-0.090	-0.014	0.085	0.04, 0.002
	513	(0.404)	(0.883)	(0.381)	(0.658)
	Female	0.027	-0.083	0.027	0.033, 0.001
	626	(0.802)	(0.460)	(0.807)	(0.717)
RiskNano	**All**	0.029	-0.614	0.234	0.329, 0.108
	1165	(0.675)	(0.000)	(0.001)	(0.000)
	Male	-0.181	**-0.449**	0.180	0.235, 0.055
	513	(0.091)	(0.000)	(0.062)	(0.000)
	Female	0.086	**-0.412**	**0.274**	0.207, 0.043
	626	(0.363)	(0.000)	(0.006)	(0.000)
RiskGenEn	**All**	-0.23	-0.208	0.141	0.126, 0.016
	1165	(0.749)	(0.001)	(0.050)	(0.000)
	Male	0.081	**-0.288**	-0.016	0.133, 0.018
	513	(0.463)	(0.003)	(0.875)	(0.011)
	Female	-0.153	0.114	**0.283**	0.110, 0.012
	626	(0.128)	(0.286)	(0.008)	(0.022)
RiskICT	**All**	-0.283	-0.071	0.419	0.184, 0.034
	1165	(0.000)	(0.235)	(0.000)	(0.000)
	Male	-0.306	-0.111	**0.451**	0.221, 0.049
	513	(0.004)	(0.221)	(0.000)	(0.000)
	Female	-0.277	0.068	**0.401**	0.146, 0.021
	626	(0.008)	(0.535)	(0.000)	(0.001)

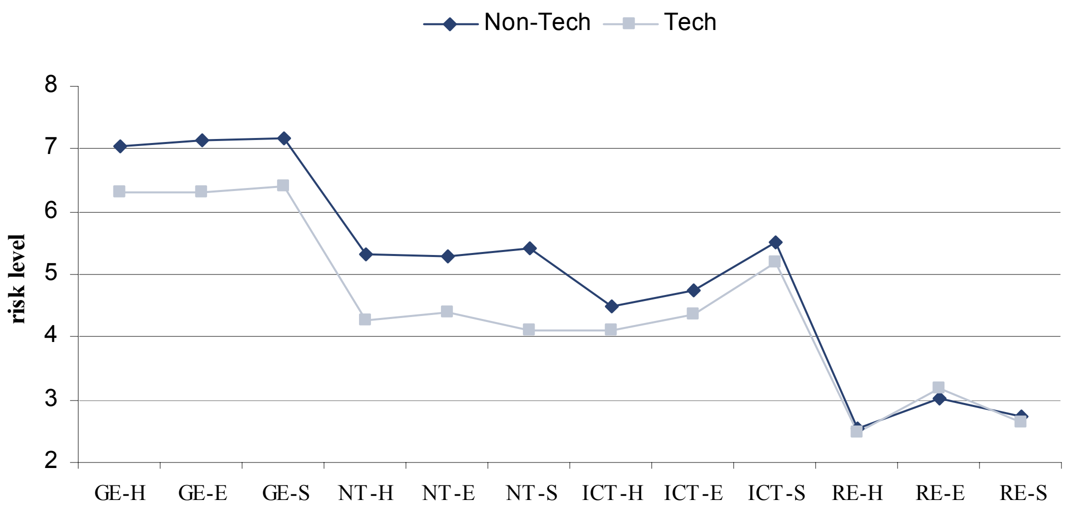
Figure 1: Risk perception of female students in technical and non-technical study areas



GE=genetic engineering, NT=nanotechnologies, ICT=information and communication technologies, RE=renewable energies

H=health, E=environment, S=society

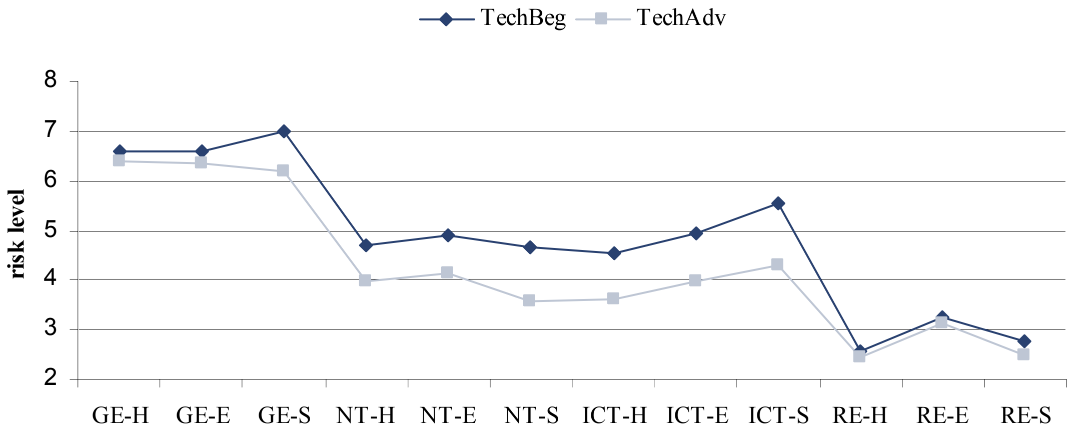
Figure 2: Risk perception of male students in technical and non-technical study areas



GE=genetic engineering, NT=nanotechnologies, ICT=information and communication technologies, RE=renewable energies

H=health, E=environment, S=society

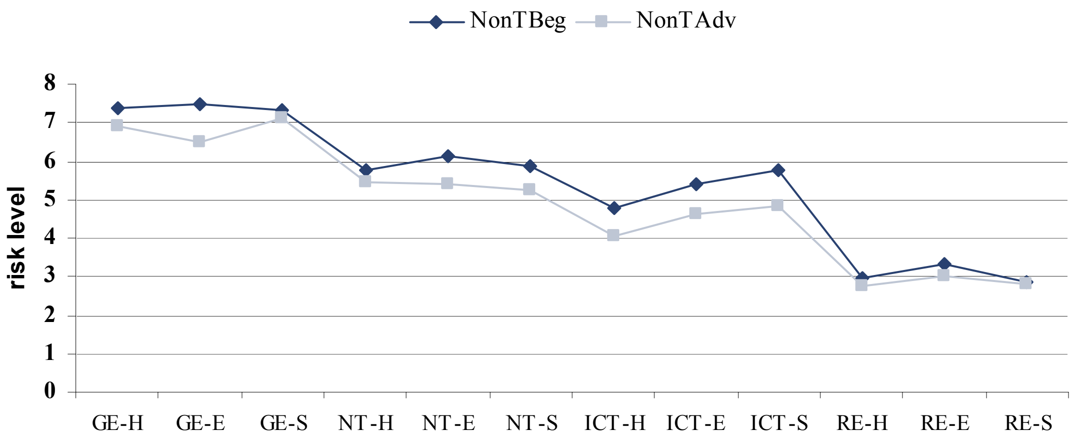
Figure 3: Risk perception of students in technical study areas: beginners and advanced students



GE=genetic engineering, NT=nanotechnologies, ICT=information and communication technologies, RE=renewable energies

H=health, E=environment, S=society

Figure 4: Risk perception of students in non-technical study areas: beginners and advanced students



GE=genetic engineering, NT=nanotechnologies, ICT=information and communication technologies, RE=renewable energies

H=health, E=environment, S=society