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Exploring Students' Ideas About Risks and Benefits of Nuclear Power Using Risk Perception Theories

Ahmet Kılınç · Edward Boyes · Martin Stanisstreet

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Abstract Due to increased energy demand, Turkey is continuing to explore the possibilities of introducing nuclear power. Gaining acceptance from local populations, however, may be problematic because nuclear power has a negative image and risk perceptions are complicated by a range of psychological and cultural factors. In this study, we explore the views about nuclear power of school students from three locations in Turkey, two of which have been proposed as sites suitable for nuclear power plants. About half of the student cohort believed that nuclear power can supply continuous and sufficient electricity, but approximately three quarters thought that nuclear power stations could harm organisms, including humans, living nearby. Rather few students realized that adoption of nuclear power would help to reduce global warming and thereby limit climate change; indeed, three quarters thought that nuclear power would make global warming worse. There was a tendency for more students from the location most likely to have a nuclear power plant to believe negative characteristics of nuclear power, and for fewer students to believe positive characteristics. Exploration of the possible nuclear power programmes by Turkey offers an educational opportunity to understand the risk perceptions of students that affect their decision-making processes.

A. Kılınç (✉)
Elementary Science Education Department, Faculty of Education, Ahi Evran University, Terme cad, 40100 Kırşehir, Turkey
e-mail: ahmet_tr@yahoo.com

E. Boyes · M. Stanisstreet
Environmental Education Research Unit, University of Liverpool, Liverpool L69 3BX, UK

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Introduction

Today's citizens are confronted with a number of 'socio-scientific' issues. These are issues that have a basis in science, are frequently at the frontiers of scientific knowledge, and involve forming opinions and making choices at personal or societal levels. Such opinions and decisions require some cost-benefit analysis in which potential harm, for example to human health or the environment, interacts with values. They also need some understanding of probability and risk (Ratcliffe and Grace 2003). Furthermore, socio-scientific issues may involve disagreements among experts and authority figures (Kolsto 2006; Sadler 2004; Solomon 1989; Zeidler 2003). For example, the prime minister of Turkey, Recep Tayyip Erdoğan, announced that he and his family would not have vaccination for swine influenza, whereas the minister of Health, Recep Akdağ, did not share the same idea (Hurriyet Daily News 2009). Perhaps because of their controversial nature, socio-scientific issues are frequently reported in the popular media. In such circumstances, even if the information is presented in an accurate and unbiased manner, students may generate idiosyncratic ideas and, because communication is one-way, these misconceptions may go unchallenged. Given the scientific, logical and ethical complexities of socio-scientific issues, it is unlikely that traditional educational practice in which science is presented mainly as a factual system will properly equip the up-coming generation to make decisions about them.

Society currently faces a range of socio-scientific issues such as genetically modified organisms, nanotechnology,

gene therapy and nuclear power generation. The last of these is especially pertinent to students in Turkey, partly because it displays many of the characteristics of a socio-scientific issue, and partly because Turkey is investigating potential sites for its first nuclear power stations, so the issue has some profile in the national media. In reality, nuclear power presents both advantages (benefits) and disadvantages (risks). Generation of power from nuclear sources produces fewer greenhouses gases that contribute to global warming and climate change than generation of electricity from carbon-based sources. In the light of the imminence and severity of the environmental (IPCC 1997, 2001, 2007), social (Solana 2008), health (IPCC 2007) and economic (Stern 2006) consequences of global warming, non-carbon sources of energy have become increasingly important. Indeed, even if renewable sources can eventually supply the world's energy needs, they are unlikely to be able to do so in the near future, and so nuclear power may be the only way to fill the energy 'gap' (Pagnamenta 2009; Ulutas 2005). On the other hand, the incidents at Three Mile Island, Chernobyl and, more recently, Fukushima, draw attention to the fact that nuclear power generation is not risk-free, so risk perception is a particularly important aspect of determining the acceptability or otherwise of nuclear power (Sjöberg 2000a).

Models of Risk Perception

Risk perception by individuals includes an informal estimation of the probability of an event happening combined with an evaluation of how concerned they would be about the negative consequences of such an incident (Sjöberg et al. 2004). Risk itself cannot be directly sensed, only the dangers and threats that contribute to it. So risk is different from perception in the technical sense of the word as used in the literature of psychology of perception and sensation (Sjöberg 2000b). For individuals, risk is seldom connected with a formal calculation, and mathematical analysis of the risk is usually intractable or even irrelevant. Rather, risk perception is a question of beliefs about the risk and, as such, it is akin to many other attitudinal phenomena that have been investigated by social psychologists (Frewer et al. 2004; Sjöberg 1998, 2000a, b).

A number of models have sought to explain people's perceptions of risk, including the 'psychometric paradigm' and the 'cultural theory'. The former is rooted in the disciplines of psychology and decisions science (Sjöberg et al. 2004), and assumes that risk is perceived by a combination of factors such as voluntariness, dread, control, knowledge, catastrophic potential and equity. In many studies of the risks associated with nuclear power, however, these psychological factors have been subsumed into two dimensions, 'unknown' and 'dread' (Fischhoff et al. 1978; Sjöberg et al. 2004; Slee and Cross 1989; Slovic 1996; Sohn et al. 2001). The 'unknown' dimension is characterised by the newness of the hazard, the degree to which its dangers are unobservable, and the delayed mechanism of the harm (Sohn et al. 2001). 'Dread' is characterised by a lack of control over the risk, the potential for catastrophic final consequences and the degree to which the distribution of risk is inequitable.

According to the cultural theory, people's perceptions of risk are influenced by their cultural background (Brenot et al. 1996)—that is, by worldviews or ideologies that entail deeply held beliefs and values that are themselves the product of different patterns of socialization (Wildavsky and Dake 1990). In terms of risk perception, there are four classes of such values: egalitarianism, hierarchy, individualism and fatalism (Adams 1995; Brenot et al. 1996; Yim and Vagenov 2003). An egalitarian is someone who is sensitive to risk issues and cares about others, and so requires that there is an equal distribution of risk across society and that all potentially affected individuals have an equal voice. In contrast, a hierarchist employs the utilitarian approach and believes that it is acceptable to compromise the safety of a minority in order to maximize the safety of the majority. Persons holding such views also tend to use technical rational argumentation, and to trust government or industry for the management of risk. For the third group, the individualists, potential personal benefits and injury are more important in their perception of risk. Lastly, the fatalists tend to be pessimistic about social systems and risks from them (Yim and Vagenov 2003). In general, people endorsing egalitarian and individualistic views perceive more risk in chemical pollutants than those with other viewpoints (Bouyer et al. 2001). People holding hierarchical positions perceive less risk in nuclear energy; in contrast, those with a fatalistic perspective perceive more risk in nuclear energy. People who endorse egalitarian views tend to perceive health hazards as more risky than the people who do not endorse such a view (Bouyer et al. 2001; Yim and Vagenov 2003).

In addition to these theories, Alhakami and Slovic (1994) stressed that people perceive and react to risk in two fundamentally different ways. 'Risk as feelings' refers to individuals' instinctive and intuitive reactions to danger, whereas 'Risk as analysis' brings reason and scientific deliberation to bear on risk management. Reliance on risk as feelings is described as the 'affect heuristic' (Slovic and Peters 2006), because it involves a mental short-cut (Finucane et al. 2000). The representations of objects and events in people's minds are tagged to varying degrees with affect; in the process of making judgments people then consult a mental 'affect pool'. Just as memorability, imaginability and similarity serve as cues for probability judgments, affect may serve as a cue for many important

judgments. Using an overall, readily available, affective impression can be more efficient than evaluating advantages and disadvantages, or retrieving from memory many relevant examples, especially when the required judgment is complex, or an individual's cognitive base is limited (as in the case of nuclear power). According to the affect heuristic, although risk and benefit may, in reality, be positively correlated, numerous studies have shown them to be negatively related in people's minds. In addition, if people's feelings towards an activity are favorable, they tend to judge the risks as low and the benefits as high; if their feelings toward the activity are unfavorable, they tend to make the opposite judgment of high risk and low benefit (Finucane et al. 2000; Slovic and Peters 2006).

Nuclear Power and Turkey

It can be seen, therefore, that lay perceptions of the risks associated with nuclear power will be complicated by a number of cultural and psychological factors. Furthermore, the socio-scientific aspects of nuclear power, like other socio-scientific issues, are touched upon little in formal education environments such as school or university, and so people obtain most of their information (and sometimes perhaps mis-information) from informal sources such as family, friends and, especially, the popular media (Boyes and Stanisstreet 1994; Freudenburg et al. 1996; Sjöberg et al. 2004). The popular media have a number of disadvantages as sources of information. There may be a tendency to use emotive language (Ratcliffe and Grace 2003) or, because reports are brief, they may not provide enough information to alleviate any fears they might trigger (Wahlberg and Sjöberg 2000). Furthermore, concepts involving probability have long been known to be difficult for lay people (Fischhoff 1995). Thus, many people will use a lay reasoning based on limited and perhaps erroneous information in an attempt to reach an opinion about the risks and benefits of nuclear power.

The fact that the public may not be well equipped to reach decisions about the advantages and potential hazards of nuclear power is of particular importance to Turkey. Over the past decades, Turkey's demand for energy has been rapidly increasing as a result of synergistic factors such as industrialization, urbanization and rapid population growth. Although there are alternative strategies to satisfy some of the increasing energy demand (parts of Turkey have the potential for wind or hydroelectric power plants, for example), nuclear power is an option that is under serious consideration. Studies in preparation for building a nuclear power plant were initiated in 1965. Following various site-selection reports, the Turkish Electricity Institution proposed in 1975 that Akkuyu near to the city Mersin on the Mediterranean coast was a suitable site for a nuclear facility. Due to various political and financial difficulties, the project was subsequently cancelled. In 1993, the Turkish High Council of Science and Technology identified nuclear energy generation as the third highest priority project for the country and, as a consequence, a nuclear plant project was included in the 1993 investment plan. Although the nuclear programme was later postponed until the country's economy improved, in 2005 the Government again announced that it wanted to re-start the programme. The proposal is that construction of at least three nuclear power plants should be started in 2015 (Turkish Atomic Energy Authority 2009). In 2009, the Turkish Energy Minister, Taner Yildiz, reaffirmed the Government's commitment to the nuclear power programme and identified Sinop, a province on the Black Sea coast, as a location for Turkey's second nuclear power plant. Moreover, despite the recent disaster at Fukushima, the Turkish Prime Minister and Minister of Energy have emphasised that Turkey's nuclear power program will continue and that there will be no change in their plans to build nuclear plants at Mersin and Sinop (Hurriyet Daily News 2011).

Aims of the Present Study

In the light of Turkey's continuing commitment to nuclear power, the need to convince some members of the population of the acceptability of building nuclear power plants in their locality, and the inherent difficulty that many citizens will have in evaluating the level of risk involved, the present study aims to explore views of the up-coming generation of Turkish citizens about nuclear power. More specifically, we have attempted to:

1. Determine the beliefs of Turkish school students about the characteristics, positive (benefits) and negative (risks), of nuclear power.
2. Determine the views of Turkish school students about how important those characteristics are.
3. Compare the preponderance of these beliefs and views in students from three cities, one of which is close to a potential site for a nuclear plant (Mersin), one of which is close to a possible site for a nuclear facility (Sinop), and one of which has no potential to act as a site for a nuclear plant (Kırşehir).
4. Compare the preponderance of these beliefs and views in male and female students.
5. Compare the preponderance of these beliefs and views in students across the grades.
6. Explain the results using current models of risk perception.

Methods

Design of the Questionnaire

The closed-form questionnaire used in this study consisted of four sections, preceded by a coversheet that asked students to record their Year Group, age, city of residence and gender. The language of the questionnaire was Turkish, although the wording of items and the available responses are given here in English. The general format of the questionnaire, was designed to seek students' beliefs about the characteristics of nuclear power generation and then, separately, to probe their views about the importance of such characteristics. This format has been used previously, although in the context of a different issue (Kılınç et al. 2013). The individual questionnaire items were designed to incorporate various ideas about nuclear power generation; some of these ideas have been explored previously with English students (Driver et al. 2010).

The first section contained three items asking students whether they would be willing to pay more for electricity made from nuclear power stations, whether they would pay more if everyone else did, and whether they would be prepared to live near a nuclear power station. These items represented possible real decisions to be made in the case of building a new nuclear plant. The available responses for these items were 'I strongly agree', 'I agree', 'I neither agree nor disagree', 'I disagree' and 'I strongly disagree'. The second section of the questionnaire contained the main items that probed students' beliefs about possible characteristics, positive (benefits) and negative (risks), of electricity generation by nuclear power; these items were designed to represent some specific risk perceptions about nuclear plants. For example, one item was 'It is cheaper to make electricity by nuclear power than by other methods'. The available responses here, as previously, ranged from 'I strongly agree' to 'I strongly disagree'. Items in the third section of the questionnaire probed the second aspect of this research and asked students their views about the importance of some characteristics of electricity generation in general; in the main, these items paralleled those in the previous section of the questionnaire. For example, the question parallel to the item above was 'How important is it to you that using your electricity doesn't cost too much?'. The responses provided here were 'very important', 'quite important', 'not very important' and 'not at all important'. The concluding, smaller, section to the questionnaire contained four items (Table 1). The first of these asked students how worried they were about what global warming might do to the environment. Here the responses were 'I am very worried', 'I am quite worried', 'I am a little bit worried' and 'I am not at all worried'. The second item asked students how much they thought they knew about global warming; the responses were 'a lot', 'something', 'a little' and 'nothing at all'. The third item in this final section asked students to report how environmentally friendly they thought they were, with 'very', 'quite', 'a bit' and 'not at all' as responses. The final item asked students

Table 1 Turkish students' general views about nuclear power generation and about global warming

	Overall (%)	Gender		City				Grade	
		Males (%)	Females (%)	Mersin (%)	Sinop (%)	Kırşehir (%)	Ranking	6 (%)	10 (%)
Would pay more for nuclear power	22			20	12	30	***S = M < K	27*	19
Would pay more if others also paid more	28			21	20	40	***S = M < K		
Would not want to live near nuclear power station	81			86	85	76	***S = M > K		
Do you think global warming is happening now?	93	91*	95					91*	94
How worried are you about global warming?	90	87***	94	93	90	89	**S = K < M	92***	91
How much do you know about global warming?	91			94	91	89	**S = K < M	91***	91
How 'environmentally friendly' are you?	83	79**	87	88	87	76	**S = M > K	86***	80

Data for the top three rows show combined percentages of students who 'strongly agree' or 'agree' with the statement. Data for the bottom four items show the percentages of students who are 'very' or 'quite' worried; who report knowing 'a lot' or 'something' about global warming; who consider themselves 'very' or 'quite' environmentally friendly; who are 'sure' or 'think' global warming is happening now. Differences between the responses of subsets of students were explored using ANOVA tests. Rankings in the responses of students in different cities were explored using the Tukey test. Trends in the responses of students in different grades were confirmed using ANCOVA tests. The responses of different subsets of students are shown only where they are significantly different, as indicated by asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

if they believed that global warming was really happening now. The responses to this item were 'I am sure global warming is happening', 'I think global warming is happening', 'I don't know whether global warming is happening or not', 'I think global warming is not happening' and 'I am sure global warming is not happening'.

Administration of the Questionnaire

The questionnaire was completed by school students in three Turkish cities; these cities were selected because they have different prospects of having a nuclear power station built in their vicinity. Kırşehir is a city in central Turkey and there are no current plans for constructing a nuclear power station at this location. Sinop is a city to the north, on the Black Sea coast, and some investigations have been carried out to determine the feasibility of constructing a nuclear power station near this town. Mersin is a city on the Mediterranean coast, and there have been proposals to site one of Turkey's first nuclear power plants near this location. Inevitably, there were some differences between the cities in addition to their potential for the construction of a nuclear power plant. For example, Mersin is a large city (population approximately 1.3 million), whereas Kırşehir and Sinop are smaller (populations approximately 150,000 and 100,000 respectively). In terms of socio-economic indices (which included parameters such as literacy rate, perinatal mortality and income) Mersin, Kırşehir and Sinop were 17th, 42nd and 57th among 81 cities in Turkey (Turkish Statistics Institution 2009). In order to reduce the possible effect of some of these variables on the responses, schools were purposefully selected, following advice from Ministry of Education experts in the cities, to have a middle level of achievement and social status catchment areas. Data capture was finished some time before the incident at the nuclear facility at Fukushima in Japan in March 2011.

Questionnaires were completed in normal classroom lessons, in the presence of the students' usual school teacher and one of the researchers. The questionnaires were completed individually, under 'examination conditions', although no time limit was imposed. Students were assured that their responses would be anonymous, so that "no-one would know what they had written."

Statistical Analyses

The responses from the completed questionnaires were encoded into SPSS for analyses. Differences in the distribution of responses between male and female students, between students in different grades, and between students from the three cities were examined using ANOVA. Trends in the responses of students in different grades were confirmed using ANCOVA. Rankings in the responses of students in different cities were explored using the Tukey test. Cronbach's Alpha for the items of the questionnaire and the data concerned was 0.63, indicating an adequate degree of reliability.

Results

Characteristics of the Respondent Group

In all, 2,253 students completed the questionnaire. Some 40 % of these were from Kırşehir, 29 % were from Sinop and 31 % were from Mersin. The distribution across the grades was as follows: 19 % were in Grade 6; 22 % in Grade 7; 21 % in Grade 8; 21 % in Grade 9 and 17 % in Grade 10. Some 49 % of the respondents were male students; 51 % were female.

For items in some of the sections of the questionnaire, rather than discuss the percentages of all possible response categories, a single figure for each item has been reported, for clarity. For example, in the second section of the questionnaire the figures were obtained by combining the two categories 'strongly agree' and 'agree'. When this has been done it will be stated at the appropriate point. Where statistically significant differences between male and female students were observed (ANOVA, $p < 0.05$), the percentages for the males are given first, followed by those of the females. If statistically significant differences between the responses of students in different grades and trends across the grades were found (ANCOVA, $p < 0.05$), the percentages given are those for Grade 6, followed by those for Grade 10. Where differences were found between the responses of students from different cities (ANOVA, $p < 0.05$), the percentages given are those for Mersin, followed by those for Sinop, then those for Kırşehir.

Students' General Views About Nuclear Power and About Global Warming

The responses to items in the first, shorter, section of the questionnaire, those exploring students' general views about nuclear power, are shown in Table 1. Overall, about a quarter of the students (22 %) reported a willingness ('strongly agree' plus 'agree') to pay a price premium for electricity made from nuclear power, although this willingness decreased in older students (27, 19 %). Students from Kırşehir appeared to be most willing to pay a price premium for nuclear power, whereas students from Sinop were least willing (Mersin 20 %, Sinop 12 %, Kırşehir 30 %). The overall proportion of students willing to pay more for nuclear power increased slightly (28 %) in circumstances in which everyone was obliged to do this. As above, more students from Kırşehir would be willing pay

more under these circumstances to do this (21, 20, 40 %). However, more than three quarters of the students overall (81 %) would not want to live near to a nuclear power station. Interestingly, this applied less to students from Kırşehir (86, 85, 76 %), where there are no prospects of constructing a nuclear facility.

When it came to students' views about global warming, explored in the final section of the questionnaire, the results showed that almost all of the students (93 %) thought that global warming is already happening, and about half of them (47 %) were sure of this, although the proportion who were sure decreased across the grades (54, 39 %). More females than males thought that global warming was happening (91, 95 %). The majority of students (90 %) were concerned about the effects of global warming on the environment, and more than half (59 %) were very worried. Fewer males than females were concerned (87, 94 %), and this concern diminished over the age groups (92, 91 %), particularly for students who were very worried (67, 52 %). More students from Mersin were concerned about the environmental effects of global warming, as shown by the proportions of students who were very worried (Mersin 63 %, Sinop 57 %, Kırşehir 58 %). More than three quarters of the group (83 %) thought that they were environmentally friendly, although far fewer (28 %) considered themselves very environmentally friendly. More females than males (79, 87 %) considered themselves to be environmentally friendly, and fewer of the older students believed this about themselves (86, 80 %). Fewer students from Kırşehir considered themselves very environmentally friendly (28, 32, 25 %). Most of the students (91 %) thought that they knew at least 'something' about global warming, although only about a quarter (24 %) reported that they knew 'a lot' about global warming. There was a reduction across the grades in the percentages of students who reported knowing 'a lot' (32, 16 %). More of the students from Mersin considered themselves well informed about global warming (27, 23, 22 %).

Students' Beliefs About Possible Characteristics of Nuclear Power Generation

In the descriptions below and in Table 2, the percentages given are for those who 'strongly agreed' or 'agreed' with the proposition. Some of the items in this section of the questionnaire concerned possible beneficial characteristics of nuclear power generation compared with electricity generation by other means. Many students appeared convinced of the advantages of nuclear power in terms of sufficiency and security of supply. More than half (59 %) thought that nuclear power stations could provide sufficient power for everyone, and a similar proportion (54 %) believed that nuclear power stations could supply electricity reliably. Fewer considered nuclear energy had advantages in terms of economy, with only about a third (33 %), thinking that it is cheaper to make electricity from nuclear sources. Even fewer (18 %) thought that adoption of more nuclear power would help to reduce global warming. Finally, few students (16 %) thought that nuclear power stations were safer than other types of power station.

This last belief was complemented by the responses to some of the items concerned with possible risks of nuclear power stations. For example, many students thought that nuclear power stations could harm the people (85 %), plants (85 %) or animals (83 %) that live near them, perhaps because many students (81 %) believed that radioactive material can leak out of nuclear power stations. As well as direct harmful effects on living organisms, about three quarters of the respondents (77 %) thought that radioactivity somehow makes global warming worse. Many students also thought that decommissioning nuclear power stations would be problematic; about three quarters (78 %) believed that there will be difficulties in getting rid of the radioactive waste from nuclear power stations, and about half (48 %) thought that nuclear powers stations will cost more to close down than other types of power station. Perhaps because they are aware of the negative views about nuclear power held by their peer group, about three quarters of the students (70 %) thought that most teenagers look down on the idea of making electricity from nuclear power, and believe that those who support it are damaging the environment.

Some differences were found between the views of male and female students about the characteristics of nuclear power generation. More males than females believed in the benefits of nuclear power generation. For example, more males than females tended to believe in the technological advantages of nuclear power, thinking that nuclear power stations could supply enough electricity for everyone (65, 53 %), that they can make electricity available continuously (58, 51 %), and that it is cheaper to make electricity from nuclear power than by other methods (37, 28 %). More males also thought that nuclear power could make a contribution to reducing global warming (20, 16 %). In contrast, more of the female students tended to accept the negative characteristics of nuclear power. So, more females than males thought that nuclear power stations can harm the people (83, 87 %) and plants (83, 87 %) that live near them, that radioactivity makes global warming worse (73, 81 %), and that there are going to be problems in the future getting rid of the radioactive waste from nuclear power stations (76, 81 %). More females than males also thought that teenagers look down on the idea of making electricity from nuclear power, and think that those who support it are damaging the environment (67, 73 %).

Table 2 Turkish students' views about possible advantages and disadvantages of nuclear power generation

	Overall (%)	Gender		City				Grade	
		Males (%)	Females (%)	Mersin (%)	Sinop (%)	Kırşehir (%)	Ranking	6 (%)	10 (%)
Advantageous characteristics									
Nuclear power can make sufficient electricity	59	65***	53						
Nuclear power stations can supply continuous power	54	58***	51					54*	56
Nuclear power is cheaper than other forms	33	37**	28	30	34	33	**S = M < K	29**	40
Use of nuclear power would reduce global warming	18	20**	16	14	11	26	***S = M < K		
Nuclear power is safer than other forms	16			11	11	25	***S = M < K		
Disadvantageous characteristics									
Nuclear power stations are expensive to close down	48			54	54	40	***K < S = M	38***	57
Teenagers think nuclear power damages environment	70	67**	73	79	73	62	***K < S < M		
Radioactivity makes global warming worse	77	73***	81	83	73	76	***S = K < M		
Radioactive waste is difficult to dispose of	78	76**	81	82	80	75	***K < S = M		
Radioactive material could leak from power stations	81	81**	82	83	86	76	***K < S = M		
Nuclear power stations can harm animals	83			88	85	77	***K < S < M	83***	79
Nuclear power stations can harm people	85	83***	87	89	84	82	***K = S < M	88**	86
Nuclear power stations can harm plants	85	83**	87	89	86	82	***K < S < M		

Data show combined percentages of students who 'strongly agree' or 'agree' that nuclear power generation has the characteristic shown. Here, positive characteristics are shown in the upper section of the table, in descending order of popularity; negative characteristics are shown in the bottom section of the table, in ascending order of popularity. In the actual questionnaire, items were in random order. Differences between the responses of subsets of students were explored using ANOVA tests. Rankings in the responses of students in different cities were explored using the Tukey test. Trends in the responses of students in different grades were confirmed using ANCOVA tests. The responses of different subsets of students are shown only where they are significantly different, as indicated by asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

For some items in this section of the questionnaire there were differences in the responses of students in different grades. Thus, more of the older students believed that nuclear power stations could produce power continuously (54, 56 %), that nuclear power is cheaper than other forms of energy generation (29, 40 %), but that nuclear power stations are more expensive to close down (38, 57 %). In contrast, fewer of the older students believed that nuclear power stations could harm animals (83, 79 %) or people (88, 86 %) in the locality.

Some differences were found in the views of students from different cities about possible characteristics of nuclear power generation. In general, where these differences were statistically significant, more students from Kırşehir, the city least likely to have a nuclear power facility, believed in the possible benefits of nuclear power. For example, more students from Kırşehir thought that use of nuclear power would contribute to a reduction in global warming (Mersin 14 %, Sinop 11 %, Kırşehir 26 %), and more believed that it was a cheaper (30, 34, 33 %) and safe (11, 11, 25 %) form of power generation. In a complementary manner, more students from Mersin, the city most likely to have a nuclear power plant, believed in the risks of nuclear energy generation. So, more students from Mersin thought that nuclear power stations could harm the people (89, 84, 82 %), plants (89, 86, 82 %) and animals (88, 85, 77 %) that live near them. Perhaps this is connected to the beliefs that many students from Mersin also believed that radioactive material may leak out of nuclear power plants (83, 86, 76 %) and that radioactivity makes global warming worse (83, 73, 76 %). More students from Mersin also saw practical and financial disadvantages in nuclear power plants, in that they thought that radioactive material was difficult to dispose of (82, 80, 75 %) and believed that they are expensive to close down (54, 54, 40 %). More students from Mersin also thought that nuclear power has a poor

Table 3 Turkish students' views about the importance of possible characteristics of power generation

	Overall (%)	Gender		City				Grade	
		Males (%)	Females (%)	Mersin (%)	Sinop (%)	Kırşehir (%)	Ranking	6 (%)	10 (%)
How important is it that…									
… the power station does not harm people?	77	73***	80	79	81	71	***S = M > K	91***	97
… the power station is safe?	74			76	75	70	***S = M > K		
… your electricity does not increase global warming	67	63***	72	73	66	64	***S = K < M		
… your friends respect you	66	62***	70						
… the power station does not harm animals?	65	61***	70	95	96	91	*S = M > K		
… the power station does not harm plants?	63	59***	67	64	68	59	**S = M > K		
… your electricity supply is reliable?	46			45	38	54	***S = M < K	88***	94
… your electricity does not cost too much?	27	31**	23	25	22	31	**S = M < K	78*	74

Data show percentages of students who thought that the characteristic was 'very' important. Here, characteristics are in descending order of importance; in the actual questionnaire, items were in random order. Differences between the responses of subsets of students were explored using ANOVA tests. Rankings in the responses of students in different cities were explored using the Tukey test. Trends in the responses of students in different grades were confirmed using ANCOVA tests. The responses of different subsets of students are shown only where they are significantly different, as indicated by asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

image amongst their contemporaries, who think that supporting nuclear power is contributing to environmental degradation (79, 73, 62 %).

Students' Views About the Importance of Characteristics of Power Generation

A high proportion of the students thought that most of the characteristics of power generation were either 'very' or 'quite' important. So, in order to differentiate between students' views about the importance of different characteristics, in this section the percentages given in Table 3 and the descriptions below are for those who gave the response that the characteristic was 'very important'. Safety appeared central in students' views, with three quarters (74 %) thinking it very important that the power station that makes their electricity should be safe. More specifically, high proportions of students responded that it was very important that the power station did not harm the people (77 %), animals (65 %) or plants (63 %) that live near it. Two thirds of the students (67 %) also thought it very important that electricity generation does not harm the environment in terms of increasing global warming. Rather fewer, about half (46 %) considered reliability of supply very important, and only a quarter (27 %) seemed to think that cost of electricity was of major importance. In a rather different dimension, but representing a possible important environmental motivator, two thirds of the students (66 %) felt that the respect of their friends was very important to them.

There were differences in the responses of male and female students for most of the items, and for all but one item more of the female students felt that the characteristic was 'very important'. So, more females thought that it was very important that people (73, 80 %), animals (61, 70 %) or plants (59, 67 %) are not harmed by electricity generation, and that global warming is not increased (63, 72 %). More females also thought that the respect of their peers was important (62, 70 %). The opposite was true for the item concerning the cost of electricity, where more boys than girls thought it was very important (31, 23 %).

For three items in this section of the questionnaire there were differences in the responses across the grades. Thus, more of the older students thought it very important that power stations do not harm people who live nearby (91, 97 %), and that their electricity supply is reliable (88, 94 %). In contrast, fewer of the older students felt it very important that electricity does not cost too much (78, 74 %).

When it came to the responses of students from different cities within Turkey, the differences depended on the questionnaire item. So, fewer of the students from Kırşehir, the city least likely to develop a nuclear power station, appeared very concerned about safety, both in general (Mersin 76 %, Sinop 75 %, Kırşehir 70 %) and in more specific terms of harming people (79, 81, 71 %) or plants

(64, 68, 59 %). In contrast, more of the students from Kırşehir than other cities thought that reliability (45, 38, 54 %) and economy (25, 22, 31 %) of electricity supply were very important. Students from Mersin, the city most likely to have a nuclear power plant, were the most concerned about the fact that power generation should not exacerbate global warming (73, 66, 64 %).

Relationship Between Belief and Importance

It might reasonably be argued that if a student believes that nuclear power has a particular benefit, and if that same benefit is deemed important by the student, then this will act as an incentive to support the adoption of nuclear power generation. If the same holds for a risk, this would act as a disincentive. Thus, the influence on a person's attitude towards nuclear power is likely to be some combination of the extent of their belief that a characteristic is true, and the importance that they attach to that characteristic. This relationship is illustrated graphically in Fig. 1. On this scatter plot, the abscissa shows the mean value of the extent to which a characteristic of nuclear energy generation is believed to be true, and the ordinate represents the mean importance attached to that characteristic. Thus, those characteristics that are located towards the upper right hand sector of the graph are those that are both believed to be true, and that are thought to be important. These then represent characteristics that are likely to act as incentives (if the characteristic is beneficial) or disincentives (if it is a risk). Figure 1 illustrates that possible leaks of radioactive material from nuclear facilities and the perceived potential to harm organisms, including humans, may act as deterrents to the acceptance of nuclear power, as may the erroneous idea that adoption of nuclear power will increase global warming. Similarly, the implication from the items in the top left of Fig. 1 where, for example, students disagree that nuclear power is safe and also think this issue is very important, is that this issue will also act as a disincentive to the adoption of nuclear power.

Discussion

The aim of this research was to study Turkish school students' views about nuclear power, using a risk perception approach, in the context that Turkey is considering building its first nuclear power stations. Nuclear power is important not only in that it has the potential to provide Turkey with a sufficient and politically independent supply of electricity, but also because, if used in place of carbon-based power generation, it may help to reduce global warming. The study sought to determine students' beliefs about the

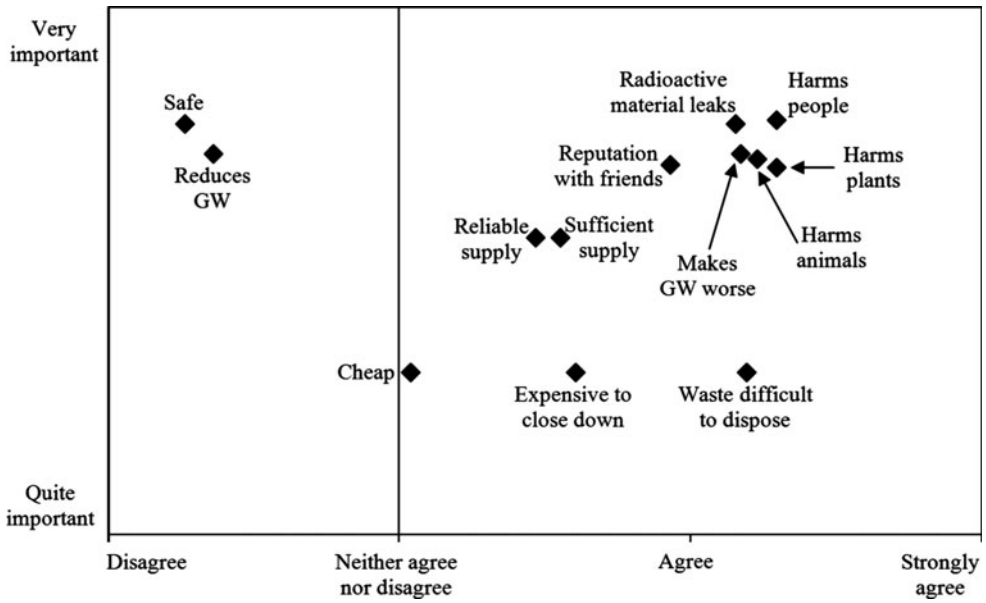

Fig. 1 Scattergram of the mean values of students' responses to items about possible characteristics of nuclear power stations and items about the importance of such characteristics. The abscissa shows the mean values of scores for students' belief in each of the characteristics of nuclear power stations, and the ordinate shows the mean values of scores for students' views about the importance of such characteristics. Labels on the abscissa and ordinate correspond to the semantic descriptors used for the various responses to the items in the questionnaire. Characteristics towards the *upper right hand section* of the *plot* are those deemed by the students to be 'real' and 'very important', and hence are likely to act as incentives (for positive characteristics) or disincentives (for negative characteristics) for supporting the adoption of nuclear power. Characteristics towards the *upper left hand section* of the *plot* may act as incentives or disincentives, depending on what is being disagreed with, although the extent of disagreement is somewhat less

characteristics of nuclear power generation and, separately, their views about the relative importance of various possible characteristics of power generation in general. By plotting these two parameters, it was possible to gain an indication of which characteristics were both believed to be true of nuclear power and felt to be important; these characteristics would represent important influences over a person's tendency to accept or reject nuclear power. In addition, because the respondents were purposefully selected from three cities with different likelihoods of being chosen as a site for a new nuclear facility, it was possible to correlate the results with students' potential proximity to a nuclear power station.

Opinions About Risks and Benefits of Nuclear Power

In the context of global warming, the majority of this cohort of students thought that global warming is really happening, perhaps anticipating the views of Turkish adults that global warming is due to human activities (BBC World Service/Program on International Policy Attitudes (PIPA)/Globescan 2007). Similarly, most of the students were concerned about the environmental consequences of global warming, again as has been shown for Turkish adults (Bang et al. 2000). Although not many students claimed to know a lot about global warming, the majority professed at least some knowledge, suggesting that knowledge about global warming may have increased in Turkish students over the past few years (Bozkurt and Cangusu 2002; Kılınç et al. 2009). Despite this, rather few students appreciated that nuclear power could contribute to a reduction in global warming; indeed, many even believed that radioactivity is a cause of global warming. We have suggested that misconceptions such as these may be based on a general mental conflation in the minds of students whereby radioactive materials are seen as a form of 'pollution', and global warming is envisaged as being caused by 'pollution', so that radioactive materials are seen as causing global warming (Boyes and Stanisstreet 1996).

The most commonly perceived benefits of nuclear power, believed by just over half of the students, were that it could produce sufficient electricity and supply continuous power; such beliefs are likely to influence views about the acceptability of nuclear power (Driver et al. 2010). These views are similar to those expressed by young people in Sweden (Drottz-Sjöberg and Sjöberg 1991), the USA (Rosa and Dunlap 1994), Japan (Komiya et al. 2008) and the UK (Driver et al. 2010), all of whom appreciated the ability of nuclear power to provide reliable supplies of electricity. Ironically, however, less than half of the Turkish respondents considered reliability of electricity supply to be very important.

Only about a third of the students believed that electricity produced from nuclear power would be cheaper than that produced from other sources, although only about a quarter of the students considered the cost of electricity to be very important. Despite this, less than a quarter of the students expresed a willingness to pay more for nuclear power, although this proportion increased slightly when the situation was presented in terms of everyone having to pay more. A similar study conducted with Year 7 and 8 Turkish students showed that a higher proportion of them, about two fifths, would be willing to pay a price premium for electricity from renewable sources (Kılınç et al. 2009), suggesting that the general negative image of nuclear power is playing a role in young people's views about whether it is acceptable to pay more for electricity made from nuclear sources. In part, this unwillingness to pay a price premium for nuclear electricity may be because rather few of the students were bothered about the personal advantages of nuclear power; for example, few were very concerned about a consistent supply of electricity.

The major disincentive to accepting the introduction of nuclear power would appear to be concerns about its safety. In general terms, very few students thought nuclear power was safer than other forms of power generation and, more specifically, the majority of students thought that nuclear power stations can harm organisms, including humans. Similar views have been found in Turkish students about renewable electricity generators, although to a lesser extent (Kılınç et al. 2009), so it may be that students consider that any large-scale technology can have at least some harmful effects on 'nature'. In the case of nuclear energy, this view is probably exacerbated by a combination of two ideas. Firstly, most of the students in the present study believed that radioactive material can leak from nuclear power stations (Driver et al. 2010). Secondly, people generally associate radioactivity with cancer (Boyes and Stanisstreet 1994; Johnson 1993; Sjöberg 1999). Furthermore, safety of nuclear power was very important to approximately three quarters of the students, as was the notion that the means of electricity generation should not harm humans. Even the safety of non-human organisms was very important to about two thirds of the students. In the light of the importance attached to safety by these students, and their beliefs in the heath risks of nuclear power stations, it is not surprising that the majority of students would not want to live near a nuclear facility.

There were some differences in the views of students across the grades. Thus, fewer of the older students were confident that global warming had already started and, perhaps as a consequence, fewer reported being very worried by it. Fewer of the older students also considered themselves well informed about global warming, although this might be because older students were more aware of

the complexities of the issue. There were also indications that older students were less pessimistic than younger students about nuclear power, with more believing that it would supply cheaper, more reliable electricity, and fewer thinking that nuclear energy plants would harm local organisms.

Interestingly, there were differences in the views of male and female students, not only in their responses about how important certain values are, but also in their beliefs about the characteristics of nuclear power plants. Thus, as well as the perceived negative characteristics such as causing harm to organisms being considered more important by the females, more females also believed that nuclear power plants did actually have negative characteristics, such as damaging the environment and harming organisms, and more males thought that they had positive characteristics, such as economy and continuity of electricity supply. The same differences in the views of males and females appear true of Turkish pre-service teachers (Ozdemir and Cobanoglu 2008; Tekbiyik and Ipek 2008). These seem to be examples of a general trend, noted in the literature, that females are more pessimistic towards new technologies that have potential effects on nature than are males (Cutter et al. 1992; Davidson and Freudenburg 1996). For example, a systematic review of 36 studies that measured gender differences in concern toward nuclear energy and waste noted that in all of these studies females were significantly more concerned than males (Davidson and Freudenburg 1996). The higher concern of females may stem from health and safety problems (Burger et al. 2000; Cutter et al. 1992; Freudenburg and Davidson 2007; Komiya et al. 2008). In addition, females tend to be more distrustful than males of institutions involving science, technology and government, particularly in relation to environmental concerns (Davidson and Freudenburg 1996).

Risk perception may also play a role in these gender differences, because a substantial body of research indicates that males and females differ in their perception of risk (Gustafson 1998). For a variety of issues females often rates risks higher than do males (Drottz-Sjöberg and Sjöberg 1991). Females generally have a risk-avoider role, whereas males have a risk-taker role (Cutter et al. 1992; Gustafson 1998). Findings on child accidents, for example, usually show that boys are more likely to have accidents than are girls, especially accidents in traffic and driving (Sjöberg and Torell 1993). As might be expected, females consider nuclear power generation high in risk (Slovic 1996), perhaps because females are more likely than males to evaluate the risks as potentailly more catastrophic (Cutter et al. 1992). Furthermore, the perception of risk associated with nuclear power may also be associated with traditional gender roles, with males focusing more on economic concerns and with females being more concerned about family, safety and health (Cutter et al. 1992; Freudenburg and Davidson 2007; Gustafson 1998). The 'economic salience hypothesis' suggests that concern about economic issues is associated with less concern about the environment. As males, particularly in traditional cultures, are expected to fulfill the role of income earner they might, according to this hypothesis, be less sensitive to environmental problems (Gustafson 1998). This situation is reflected in the findings of the present study, where male students gave more importance to the cost of electricity supplied from nuclear power, and females focused on possible harmful effects of nuclear power. Moreover, males may feel more comfortable with a rational, scientific view embodied in such disciplines as engineering, a discipline in which females have traditionally had more limited access and professional acceptance than males (Cutter et al. 1992). Related to this, Flynn et al. (1990) have suggested that males might worry less because risks are often created and handled by males, and secondly, that males might perceive risks as more acceptable than females because males benefit from risk taking (Gustafson 1998). Finally, females may in general be more risk-averse because of social stereotyping. Females may perceive social pressures to avoid risks and, as a consequence, adopt a more negative attitude to risk; the male stereotype, on the other hand, may call for a display of courage in the face of risk (Sjöberg and Torell 1993).

There were also differences between the responses of students located in the three cities, Mersin, Sinop and Kırşehir. In general, more of the students from Kırşehir, a city that has no prospect of having a nuclear power plant in close proximity, were aware of the possible beneficial characteristics of nuclear power. In a complementary manner, more of the students from Mersin and in some cases Sinop, cities in regions that have been investigated and proposed as sites for nuclear power plants, believed that nuclear facilities have negative characteristics. This might suggest that local publicity about the possible siting of nuclear facilities has raised the awareness among the inhabitants of the potential hazards of nuclear energy generation. This may be one of the reasons why students in Kırşehir were somewhat less resistant to living near a nuclear facility.

Risk Perception and Nuclear Power

In the present study, we have used possible risks and benefits to explore students' risk perceptions regarding nuclear power plants. It is likely that the concerns about nuclear power are based on a combination of the 'dread' and 'unknown' factors within the psychological paradigm. With regard to the former, 'dread', students were concerned about the final effects on organisms, and this was probably

combined with fear associated with the invisible nature of radioactivity. The latter factor, 'unknown', may have included a component of the difficulty found by the public of estimating risk. Furthermore, because Turkey has not to this point had nuclear power plants, Turkish nationals have not had experience of routine operation of such facilities within their country. This may mean that the 'asymmetry principle' (Slovic 1996) could be exaggerated. For example, the disaster at the Chernobyl nuclear plant, which is located uncomfortably close to Turkey, and the subsequent reporting of the health problems in the population close to Chernobyl, created a deep concern among the Turkish population. Consequently, Turkish citizens may be more aware of the adverse publicity surrounding major incidents in other countries than with the safe running of many nuclear power plants.

It might also be that cultural patterns interacted with the differences among the cities. Turkish people show a lower individualism score than many western cultures (Hofstede 1967–2009; Kabasakal and Bodur 1998; Pasa et al. 2001), suggesting that they have a more egalitarian orientation (Dervisoglu 2007). Thus, it might be that students who live in what may be perceived as risky places in potential proximity to nuclear power plants, Mersin and Sinop in this instance, may find the situation unfair in terms of the distribution of risk. Furthermore, health hazards are weighted more heavily by those with an egalitarian orientation (Yim and Vagenov 2003), and concern about health risks of nuclear power generation was a strong factor with the current groups of students.

In addition, the findings of the present study are generally consistent with the idea that people use the 'affect heuristic' to make judgments about risk and benefits. For example, most of the Turkish students possessed an overall unfavorable feeling about nuclear power. In part, this may be due to a sensationalist reports in the popular media, especially those local to the cities where there is a possibility of establishing a nuclear plant; such reports may emphasise the risks of nuclear energy rather than its possible benefits. This may have led Turkish students to believe that nuclear plants have big risks and small benefits. The experiments of Finucane et al. (2000), and Alhakami and Slovic (1994) show that providing information designed to manipulate affect by increasing or decreasing benefits for the technology, or by increasing or decreasing its possible risks, caused an 'overall' affect. In the present study, students' misconception about the causal relationship between nuclear power and global warming may be related to this overall unfavorable feeling, in addition to the general conflation of ideas in students' minds discussed previously. We suspect such negative beliefs might cause students to have problems in assimilating positive information about nuclear power, in that their pre-existing risk perceptions might work as a 'converter' that changes the incoming information according to existing affective framework.

Implications for Science Education

Nuclear power is a multidimensional issue. In terms of the 'risk as analysis' approach (Slovic et al. 2004), whether or not to support its introduction requires people to make a complicated cost-benefit analysis. The potential risks are themselves complex, requiring an estimation of the probability of accidental leakage of radioactive materials, combined with an understanding of the anticipated harmful effects of such an incident. Furthermore, factors such as the degree of previous exposure to information about nuclear power (which itself may be affected by bias in media coverage), gender and the likelihood of actually having to live near to a nuclear facility, have considerable effects on opinions. In terms of the 'risk as feelings' (Slovic et al. 2004), however, the affective nature of risk perceptions might also have a considerable influence on the decision-making process, and this might be reflected in the results presented here.

This raises an important question about how risk perception relates to science education. Previously, science educators (Christensen 2009; Eijkelhof 1996; Riechard and Mcgarrity 1994; Ratcliffe and Grace 2003) have tended to suggest a cognitive framework to teach about risk analysis. In such analysis, the perceived risk is quantified by considering consequences such as fatality estimates, disaster potential, loss of life expectancy and lost working days (Slovic et al. 1979; Fischhoff t al. 1984). This approach symbolises canonical science education where the main aim is to reach an expert's understanding (Roberts 2007). Indeed, the risk pscyhology literature shows that experts such as nuclear physicians and risk analysts have risk perceptions that correspond closely to the statistical frequencies of risks (Slovic et al. 1979). However, even among experts, affective and social factors play a role even in the understanding of risk and, in turn, their decisions (Sjöberg 1998). For both experts and the public in general such affective issues include moral factors, and concerns regarding health and the environment (Sjöberg 2000b). Given this background, an approach that acknowledges both 'risk as analysis' and 'risk as feeling' (Slovic et al. 2004) may be optimum for a science education about risk. In this way, students' understanding of risk and the use of statistical information could be improved by supplementing it with affect-rich images, narratives and symbols (Finucane et al. 2000).

On the other hand, the present study provided an opportunity to see how school students in what could be

perceived as 'real' risky conditions (such as ones who are living in Mersin) evaluated the risks and benefits of a technological decision compared with students in risk-free conditions. This comparison confirmed the 'affect heuristic', demonstrating that students in more risky conditions consider risks as high and benefits as low. Even though this might be expected, we consider that it has an educational merit which needs further attention. We believe that this result is a combination of the knowledge provided by informal learning environments, especially the media, and subsequent affective reasoning which restricts rational reasoning which is based on risk assesment, critical thinking and autonomous reasoning. We suggest that informal learning environments can be manipulated by journalists, politicians, and others, in order to stimulate affective elements in people's minds and thus impose predetermined goals and decisions. Therefore, purposeful educational interventions in formal environments that target critical and autonomous thinking seem promising. In such learning environments main teaching themes could include the trust in knowledge sources, the evaluation of current data regarding the risks of suggested technology, values, biases and cultural variables the stakeholders have, gender roles in decision making processes, tradeoffs between risks and benefits, understanding risk assessment tools (diagrams, graphs, etc.), uncertainties regarding scientific data and possible decision alternatives such as the precautionary principle. Also, the teaching materials should have a balanced risk–benefit perspective and provide settings where students can share their own points of view and values.

Even though risk issues are included in some countries' national standards regarding science education (National Research Council 1996), risk perception does not attract the attention of many science educators, curriculum designers or teachers. There is a limited research regarding the place of risk perceptions in science education, and this lack of evidential research and theoretical underpinning restricts the appreciation of the importance of risk perceptions in education (Christensen 2009; Gardner et al. 2010; Zint 2001). Additionally, many of the present generation of science teachers may well have received little education themselves about contemporary risk issues such as nuclear power. Furthermore, even if some teachers are willing to teach risk issues, there are few well-designed educational resources yet (Zint and Peyton 2001). Given this situation, we suggest that it is useful to study students' and teachers' ideas regarding risks and benefits of the new technologies that are taught in science classrooms, by employing strong risk perception theories. Studies such as the present study can inform curriculum designers and educators about how a risk dimension may be better embedded into science education.

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