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International Survey on Bioenergy Knowledge, Perceptions, and Attitudes Among Young Citizens

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Abstract The present study with an international perspective, investigated the state of knowledge, perceptions, and attitudes among young students toward bioenergy in Finland, Slovakia, Taiwan, and Turkey. A total of 1,903 students with an average age of 15 years from 19 rural and urban schools participated in this study. The study found statistically significant differences in students' bioenergy knowledge with respect to the countries. Only a small percentage of the students in each country were able to demonstrate a high level of bioenergy knowledge. In overall, the gender and rural–urban differences did not play a significant role in determining students' level of bioenergy knowledge. The students appeared to be very critical of bioenergy and especially of the issues related to bioenergy production from forests. They demonstrated positive attitudes in terms of their willingness to learn about bioenergy and its use in their daily life. The study found statistically significant effects of gender and locality on students' perceptions of bioenergy. Most knowledgeable students in bioenergy appeared to be most critical in their perceptions and attitudes toward bioenergy. The principal component analysis revealed three distinct dimensions of students' perceptions and attitudes toward bioenergy viz., "motivation", "critical", and "practical". A broader societal support is needed for the introduction of bioenergy in many countries and young generation's positive attitudes to this matter is certainly important for people who will create policies in this area. More efforts are needed to support young students so that they understand the multi-dimensional issues related to bioenergy by allowing them to have practical experiences with bioenergy.

Keywords Bioenergy · Knowledge · Perceptions · Attitudes · Young citizens

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Introduction

Nowadays, bioenergy has become one of the most dynamic and rapidly changing sectors of the global energy economy [102]. It is considered as a clean and renewable source of energy that could dramatically improve the environment, reduce dependency on fossil fuels and revitalize socioeconomic conditions of rural communities by creating new jobs [35]. At present, biomass is by far the largest global contributor of renewable energy (RE) and represents about 10% of global annual energy consumption, mostly used for cooking and heating [46]. It accounts for almost 80% of the total primary energy supply in many developing countries, whereas the figure is usually less than 5% in the industrialized countries [55]. In general, three main categories of bioenergy resources are used globally such as forestry biomass, agricultural biomass, and wastes biomass [78]. Despite its much benefit over fossil fuels, some recent controversies surrounding bioenergy have attracted wider international attention. Biofuels were held responsible for increasing food prices and decreasing food availability in many developing countries (see [31, 69, 101]). In addition, one can find much discussion related to the impacts of biofuel production on water scarcity [34], accelerating deforestation, and emissions of greenhouse gases in the tropical countries [29, 60, 83].

The development of the modern bioenergy sector varies greatly across countries. Currently, only a few countries have well-developed forest- and agriculture-based bioenergy sectors such as Finland, Sweden, Germany, Austria, Brazil, and the USA with their supportive policies and infrastructure [63]. However, the development of the modern bioenergy sector is in the preliminary stage in many other countries and varies greatly among those countries. Majority of studies in the past have analyzed different aspects of bioenergy production and their impacts on global economy, environment, and society (see [13, 44, 58, 59, 106]). However, none of them focused on young citizens' awareness of bioenergy from an international perspective. Young citizens are the future decision makers deciding on all aspects of society including energy issues and their positive attitudes toward REs in general and bioenergy in particular have great policy relevance. Bioenergy is a new and challenging area of development that includes several socioeconomic and environmental dimensions demanding special consideration from both energy and educational policy makers to create awareness of it among young people [39].

Theoretical Framework

The study of relations between knowledge, perceptions, and attitudes are among the most examined topics of social psychology [66]. Knowledge has been defined as a construct formed by interlinking numerous intellectual components [88] comprising of various theories and hypotheses [1]. It is generally considered that attitudes are collections of beliefs and often linked to emotional reactions and willingness to do something [107]. Unlike attitudes, perceptions describe the initial thoughts of the phenomena more than conceptions do; and they, along with attitudes, are crucial components of learning and have a causal relationship with it [107]. On environmental issues, knowledge can be regarded as synonymous with scientific literacy. It requires both adult and young citizens to take interest, understand, and be skeptical about scientific matters in order to be able to make informed decisions about environment and their own health and well-being [4, 37, 70]. Young students are particularly important from this point of view and researchers have shown that young people tend to have more environmentally positive attitudes than older people [19]. The sense of environmental citizenship among young students is rather significant. Environmental citizenship is the active participation of citizens in achieving sustainability [64]. It can be viewed as the ultimate outcome of education for sustainability that can change people's behavior by affecting their attitudes, providing access to knowledge and developing skills [42]. Environmental education contributes to behavioral changes in a given society that are ultimately translated into environmental citizenship [64].

Environmental attitudes (EA) among young students refer to a psychological tendency of individuals expressed by evaluating the natural environment with some degree of favor or disfavor [66]. A number of factors such as gender, personality traits, structural variables, and curriculum variables determine students' attitudes toward science and environmental issues [95]. Gender has been recognized as the most important factor that affects students' attitudes toward scientific topics [72]. A variety of studies have reported males to have more positive attitudes toward science (especially physical sciences) than females [52, 67, 72, 95]. However, there is also inconsistency in the previous findings as being reported in a study by Evans et al. [28] who did not find any gender differences in young people's EA. On the contrary, there are several findings to indicate females to be more concerned about environment than males [36, 81, 112]. High school appears to be a critical time for science-related experiences since gender differences in science are initially small in middle school, but become substantial during high school [50, 52, 67].

Apart from the gender factor, social structures are assumed to shape the development of an individual's values, which in turn guide the development of belief systems and worldviews [90]. Previous research has illustrated that higher income levels and higher education are associated with higher levels of environmentalism [86].

This is perhaps due to the reason that people with higher income levels generally have higher level of education and are more accustomed to living in healthy environments and thus supporting protection of environment [5, 43]. Residence also affects individuals' EA, as urban residents are generally associated with greater environmentalism since they have more exposure to environmental degradation [14]. However, the urban–rural gap in EA has been disappearing [10] and possible reasons could be the improvements in mass communication, standard of living and education, mobility, and convergence of lifestyles [19]. Nevertheless, the residency differences in EA remain for both adults and children when comparing the developed and developing countries [7, 105].

Kaiser et al. [53] reported an attitude–behavior gap that seriously limits any ambition to identify a person's attitudes by means of behavior inspection. Previous research has found that although increased awareness and knowledge are important, they have limited influence upon attitudes and behaviors of the public [21]. Culture and values often play a role to determine public attitudes and this link has often been reflected in many cross-national studies (see [33]). A significant relationship among knowledge, perceptions, and attitudes exists [76]. Nevertheless, there are contradictory findings on whether an increased understanding of a new technology can actually result in a change of students' perceptions and attitudes about the use of that technology [17]. Public attitudes are crucial in the choice of energy futures [73] since it is assumed that the greatest effects (e.g., technologies related to REs) in a society can be achieved when local viewpoints and the cultural identity of that society are considered [82]. According to Wegner and Kelly [106], "understanding technology adoption requires an understanding of how public attitudes and beliefs are formed or changed, as well as the implications of these changes for social norms". This is perhaps due to the complexities of attitudes, behaviors, and the relationship between the two [73].

Energy and Youth Perspectives

Young students' knowledge, perceptions, and attitudes toward REs are not amongst the most researched EA-related topics even though energy consumption has increased considerably among the youth [49]. It is important to raise energy awareness among young students that can transform them into sustainable energy-friendly consumers and citizens when they grow up [113]. Eurobarometer [25] survey revealed a favorable attitude among young people (15–24 years old) in Europe toward REs, especially toward solar and wind energies. Department for Business Enterprise and Regulatory Reform (BERR) [9] study revealed young citizens' (16–24 years old) ambiguity over many issues related to REs in the UK. Yuenyong et al. [111] revealed cultural differences in postulating energy-related societal and technological issues among 15-year-old ninth-grade students in Thailand and New Zealand. They reported that the Thai students regarded energy issues with the economic development of their country, which reflected an attitude common in the developing countries. On the other hand, the New Zealand students considered energy issues more with environmental conservation topics than economic issues in their country, which otherwise reflected an attitude common in the Western cultures.

Gender and locality differences in public attitudes toward REs were apparent in some previous studies. BERR [9] survey revealed that young women were less aware of REs compared to young men in the UK were. In another context, rural and urban differences in the preferences toward REs were apparent among the respondents in Scotland (see [8]). Greenberg [38] found a clear age effect in determining the preferences toward energy sources in the USA, however, that study did not include bioenergy among the possible sources of REs. Nevertheless, in that study the young American population appeared be a stronger supporter of REs related to fossil fuels; whereas, the elderly population, although supported REs like their younger counterparts, strongly supported fossil fuels and nuclear power. This has important policy relevance in the USA since the younger Americans will respond to policy initiatives and influence the governments and businesses to start developing REs rather than using fossil fuels and nuclear power [38].

In Europe, previous studies revealed a low public awareness and preference toward bioenergy compared to other REs such as solar and wind energies [2, 26, 39, 84, 93]. The reason for such public attitudes can be due to the reason that images of solar and wind energies are more visible to public as solar panels and wind mills, whereas modern bioenergy concept is more at the abstract level [39]. Only few studies have so far analyzed school students' viewpoints about bioenergy and related them to future policy implications. Halder et al. [39] revealed from a study based in North Karelia in eastern Finland that the ninth-grade students were very critical of bioenergy production from forests. Their findings also showed that the students did not have sufficient knowledge of bioenergy and they were ambivalent on a great number issues related to bioenergy. This was despite the fact that North Karelia in particular is an advanced region in producing bioenergy from forests, and energetic use of wood in the households is very common in the region. Although the North Karelian students were very critical of bioenergy, they demonstrated positive attitudes toward learning about bioenergy, however, not so eager to use it in their daily life (see [40]).

The previously referred studies generated valuable information on young students' perspectives of bioenergy;

nevertheless, there is a lack of information on young students' knowledge, perceptions, and attitudes toward bioenergy from a cross-national perspective. Global energy consumption will increase in the coming decades and bioenergy especially liquid biofuels and biomass-based heat and electricity is expected to play a key role in supplying environmental friendly energy [20, 85, 109]. In this regard, cross-national data can help energy policy makers to understand the global concerns of younger generations of bioenergy that will enable the policy makers to make internationally justified and informed decisions on bioenergy development. From the point of view of necessary energy sector cooperation, there is also need for cross-national data from countries that differ from each other not only socioeconomically and geographically but also in terms of bioenergy development. The present study from this perspective explores school students' knowledge, perceptions and attitudes toward bioenergy in Finland, Taiwan, Slovakia, and Turkey. In the following, we provide an overview of the current state of socioeconomic, energy consumption, and bioenergy development in these four countries.

Bioenergy in Finland, Slovakia, Taiwan, and Turkey

Energy and environmental issues are closely interwoven with global and national economic circumstances [104]. Finland is one of the northernmost countries in the world with a relatively cold climate [87]. It is a high-income OECD (Organization for Economic Cooperation and Development) country in the European Union (EU) with a population of 5.3 million and per capita energy consumption is about 6.9 tons of oil equivalents (TOE), which is among the highest in the world [108]. About 16% of the population in Finland is below 15 years old while about 67% is between 15 and 64 years old, which indicates an aging population structure [27]. Finland is known for its energy efficiency, especially for the combined wood and peat-fuelled heat and power production [45]. It is also one of the heavily forested countries in the world and use of wood chips for energy production has increased rapidly in the last decade in Finland [54]. Currently, 21% of the country's primary energy consumption comes from wood fuels [89]. Use of wood fuels and particularly wood chips is projected to increase in Finland over the coming years to meet the country's target of 38% renewables in the total energy consumption by 2020 under the EU Renewable Energy Directive [71].

The second country is Slovakia which is located in central Europe and 40% of the country is covered by forests [30]. It is an upper middle-income OECD country in the EU with a population of 5.4 million and per capita energy consumption is approximately 3.3 TOE [108]. Like Finland, Slovakia is experiencing an aging population. About 16% of the population is below 15 years old while about 72% is between 15 and 64 years of age [27]. Slovakia imports 90% of its primary sources of energy and the majority of it comes from Russia. Fossil fuels, natural gas, and nuclear energy constituted almost 95% of the total primary energy supply in Slovakia in 2008 and the share of combustible renewables and wastes was less than 4% [47]. However, the traditional use of wood biomass for energy is common in the rural areas [6]. One of the long-term energy policy objectives of Slovakia is to increase its share of REs up to 20% by 2020 from the present 5.5% and biomass resources have been identified as the most promising way to achieve that target amongst all the REs [68]. The use of biomass for energy production is projected to increase from the existing forests, agricultural biomass, fast growing energy crops, and residues from wood-processing industry in Slovakia [68]. This positive support from the government for bioenergy development was probably one of the reasons that made Slovakia one of the few countries in Europe where more than 70% of the respondents supported biomass energy as a future source of RE in the Eurobarometer [26] survey.

Third country is Taiwan which is situated in East Asia and the country has been experiencing rapid economic growth and energy consumption since the 1990s [74, 75]. Forests cover 58% of Taiwan according to 1995 findings and the country is home to a diverse flora and fauna [92]. Taiwan is an industrialized, high-income non-OECD country with a population of 23 million. However, it is quite similar to Finland and Slovakia regarding the age structure. About 15% of the population is below 15 years of age while 73% is between 15 and 64 years of age [103]. It imports more than 90% of its energy supply from abroad and per capita energy consumption was 4.6 TOE in 2008 [48]. Therefore, developing self-sustainable energy particularly REs including bio-diesel and bio-ethanol are of great importance for Taiwan (see [15, 62]). There are few studies in Taiwan (see [96–100]) on bioenergy and biofuels; of the research conducted, none of them had specifically focused on the social aspects related to bioenergy development. Bioenergy is now one of the main items on Taiwan's agenda for REs and the government aims to increase the production of bio-diesel by 2011; however, the limited landmass availability for biomass production is a major obstacle for large-scale bioenergy projects [62].

The last country is Turkey which is an upper middle-income OECD country with a population over 74 million and per capita energy consumption is 1.9 TOE [108]. Turkey's unique geographical location between Asia and Europe makes it a natural bridge between energy-rich Middle East and Central Asian regions [35]. It is a net energy-importing country and with its young population (27% of the population is below 15 years of age [103]),

Turkey has been one of the fastest growing power markets in the world for the last two decades [24]. Forests cover 13% of the country [30]. Biomass as a source of RE has great potential in Turkey due to the availability of vast and abundant forests and agricultural residues in the countryside [35]. Domestic energy consumption in Turkey is 37% of the total energy consumption and biomass provides 52% of it, mostly in the rural areas for heating and cooking [18, 24]. Although wood is the primary heating fuel in 6.5 million houses in Turkey, a general lack of public acceptance and willingness to utilize bioenergy is a major obstacle for bioenergy development in Turkey [24].

Aims of the Study

Based on the above discussions of young students' perspectives of REs including bioenergy and the state of bioenergy development in the four countries, the following are the objectives of the present study:

- to investigate the state of knowledge, perceptions, and attitudes and their inter-relationships among young students toward bioenergy in Finland, Slovakia, Taiwan, and Turkey;
- to find out the gender and residency (i.e., rural and urban) differences (if any) related to the students' knowledge, perceptions, and attitudes toward bioenergy; and
- to find out the structure and key dimensions of students' knowledge, perceptions, and attitudes related to bioenergy.

In addition, the study aims to find indicators for providing broader policy recommendations for increasing interactions between energy and education policies so that they can engage younger citizens in bioenergy-related discussions and increase their awareness on this topic. Given limited space, the study will primarily focus on discussing the findings with the pooled data from the four countries; however, relevant similarities and differences at the country levels will also be discussed.

Materials and Method

Selection of the Students

In each country, the researchers analyzed the national course curriculum of school education to determine the comparable target groups among the students for the study. Based on this analysis 15-year-old students studying in either ninth or tenth grades were selected from Finland, Slovakia, Taiwan, and Turkey. It was found from the course curriculum analysis that students had studied biology, physics, chemistry, and other environmental science-oriented topics; however, there was no such strong connection in their subjects with REs except in the Finnish school course curriculum. The Finnish National Core Curriculum for Basic Education includes topic such as energy conversion process (e.g., burning of wood) in the curriculum of the ninth graders. For this study, the samples were selected from urban and rural schools in each country. The urban and rural classification in each country was based on the statistics issued by each country and the researchers in each country guided the selection of the schools. No differences in the course curriculum were found in the urban and rural schools since all schools in each country followed a national guideline for basic school education.

Item Selection and Construction

The study employed a self-constructed 17-item five-point Likert-type scale (strongly agree to strongly disagree) to investigate students' perceptions and attitudes toward bioenergy (see International Bioenergy Perceptions and Attitudes Measurement Scale, IBPAMS in Table 3). The use of Likert-type scale in measuring students' EA is a common tool and was employed in a variety of studies (see [23, 51, 56, 61, 67, 76, 77]). The scoring was equated to: 5 strongly agree, 4 agree, 3 do not know, 2 disagree, and 1 strongly disagree. Total score on the scale could range from 17 to 85. The open-ended items on the survey instrument measured students' knowledge of bioenergy including other REs (solar, wind, and hydro). Curriculum analysis was necessary for constructing and selecting the items in the questionnaire most appropriate for the students considering their grades and experiences. The knowledge-related items on the REs were categorized into "low", "medium", and "high" levels to measure students' cognitive skills related to different REs. A "low" level of knowledge demonstrated some appropriate and basic facts about the REs. "Medium" level of knowledge comprised of basic scientific knowledge about the REs and some understanding about the process of producing them. A "high" level of knowledge expected sufficient information about the REs, a consistent understanding of the complexities associated with them, and examples of benefits and drawbacks. The classification of the knowledge level in this study was adjusted after the TIMSS [94] international science benchmarks study for the eighth graders.

Pilot Testing and Revision of the Initial Instrument

In each country, the researchers did a pilot testing with an initial form of the questionnaire translated into the local languages and distributed among students in a school. The same school was excluded from the final survey. The pilot testing results and feedback from the students and sugges-

tions by experts helped to improve the content validity of the final version of the questionnaire in each country.

Main Sample for the Analysis

The collection of data was conducted through a questionnaire survey from March to July 2009. The researchers in each country sent the questionnaires in paper form to the selected schools. A science teacher with relevant competence in conducting survey acted as a facilitator in each school and returned questionnaires to the researchers upon completion. The teachers were explained in advance about the objectives of the survey and they were only allowed to answer students' questions about properly understanding the survey questions. There was no incentive for the teachers to conduct the survey.

Altogether, 1,903 students participated in the survey from 19 schools (11 urban and 8 rural) in the four countries. Student participation was voluntary and anonymous and they were not offered any incentives for their participation in the survey. All students were instructed not to talk to each other and complete the questionnaire on their own. However, they were allowed to ask their teacher surveyor for properly understanding the questionnaire items. The mean age of the students was 15.34 years (S.D.=0.53); 71% were from urban area schools while 29% from the rural area schools; 47% were boys while 53% were girls. Characteristics of the each country students have been represented in Table 1. The strong female bias in the Slovakian schools was due to unknown reasons. However, a moderate to stronger gender bias has been reported in a variety of previous studies related to environment and social psychology issues among school students from Slovakia and in other countries (see [32, 53, 110]; [66]).

The students took approximately 25 min to complete the questionnaire. The survey questionnaires administered among the students were the translated versions into the local languages of each country and the researchers did the translation back into English for the analysis. Experts for maintaining a linguistically equivalent translation later validated them. The open-ended items were coded according to a codebook and performed by one researcher in Finland to avoid the problems with inter-rater reliability. The responsible authorities for education in each country approved the study. The quantitative analysis was conducted by using SPSS 17.0 program. Descriptive statistics as well as parametric and non- and parametric procedures were used in this study to find out the students' knowledge, perceptions, attitudes toward bioenergy and their relationships.

The overall reliability of the 17 items on the IBPAMS was tested by using the Cronbach's alpha which showed a satisfactory level of internal consistency (α=0.76). Item 3 was reverse scored for the reliability analysis due to its reverse meaning from the otherwise positive direction of the scale. Increasing bioenergy production leading to a decrease in food production is considered a negative impact of bioenergy. Among the 17 items on the IBPAMS, there were ten items corresponding to the students' perceptions of bioenergy (α=0.59) and seven items related to their attitudes toward bioenergy (α=0.81). The reliability of the 17 items on the IBPAMS at the country level was as follows: Finland (α=0.81), Slovakia (α=0.65), Taiwan (α=0.76), Turkey (α=0.84). The reliability analysis confirmed the effectiveness of the survey instrument and supported the correctness of statistical analyses employed in this study. Total scores related to the perceptions items on IBPAMS could range from 10 to 50; while 7 to 35 related to the attitudinal items.

Results

Students' Knowledge of Bioenergy with Gender and Locality Effects

Students were asked, in an open-ended question, to write what they knew about solar energy, wind energy, hydro energy, and bioenergy. Their answers were categorized into "low", "medium", and "high" depending on their level of knowledge related to these REs (see Table 2). Results showed that the students' level of knowledge about different REs was mainly confined to the "low" and "medium" categories. Only a smaller percentage of the students demonstrated a "high" level of knowledge of those REs. The "high" level of knowledge related to all the four

Table 1 Characteristics of the school students (N=1,903) participating in the study

Country	Number of respondents (response rate)	School distribution Urban (rural)	Students' locality distribution (%) Urban (rural)	Mean age (SD)	Gender (%) Boy (girl)
Finland	495 (79%)	4 (4)	75 (25)	15.24 (0.51)	51 (49)
Slovakia	166 (100%)	2 (1)	66 (34)	15.32 (0.73)	25 (75)
Taiwan	897 (98%)	4 (2)	73 (27)	15.43 (0.54)	45 (55)
Turkey	345 (95%)	1 (1)	61 (39)	15.28 (0.47)	57 (43)

Table 2 Descriptive of school students' (N=1,903) level of knowledge about different REs across the countries

Types	All countries				Finland				Slovakia				Taiwan				Turkey			
	n	L (%)	M (%)	H (%)	*n*	L (%)	M (%)	H (%)	*n*	L (%)	M (%)	H (%)	*n*	L (%)	M (%)	H (%)	*n*	L (%)	M (%)	H (%)
Solar energy	1,694	60	35	5	448	52	41	7	109	63	37	–	835	66	30	4	302	56	41	3
Wind energy	1,641	52	44	4	431	50	43	7	121	47	53	–	808	53	44	3	281	55	45	–
Hydro energy	1,563	68	29	3	403	61	32	7	103	63	36	1	785	74	24	2	272	64	34	2
Bioenergy	1,030	76	20	4	288	63	29	8	37	78	19	3	502	81	16	3	293	82	16	2

n number of responses to each items on renewable energy, *L* low level of knowledge, *M* medium level of knowledge, *H* high level of knowledge

REs appeared to be the highest amongst the Finnish students compared to their counterparts in the other three countries. One-way analysis of variance (ANOVA) revealed statistically significant differences across the countries related to students' overall knowledge of the REs ($F_{3,\ 1746}$=13.22, p<0.001). With respect to the level of knowledge of bioenergy, there were statistically significant differences between Finland–Taiwan (Mann Whitney U test, z=−5.39, p<0.001) and Finland–Turkey (Mann Whitney U test, z=−4.39, p<0.001); however, comparisons between other countries in pairs did not reveal any statistically significant differences in students' level of bioenergy knowledge. Mann–Whitney U tests did not also reveal any statistically significant differences in gender and residence in terms of students' level of bioenergy knowledge.

In addition, the students were asked to assess their own knowledge of bioenergy on a five-point Likert-type scale (very good=5 to very poor=1). Majority of the students (62%) rated their knowledge of bioenergy as being very poor to poor; while only about 8% of the students rated their knowledge of bioenergy as being very good to good. Almost one third of the students were undecided, as their answers fell in the category of do not know. The effect of gender was statistically significant (Mann Whitney U test, z=5.66, p<0.05) on students' self-rating of bioenergy knowledge; while the effect of residence was insignificant. About 66% of the girls rated their bioenergy knowledge as being very poor to poor against 56% of the boys who did so; while 10% of the boys rated their bioenergy knowledge as being very good to good against 5% of the girls.

Students' Perceptions and Attitudes Toward Bioenergy

There were ten items (1–10) aimed to measure students' perceptions of bioenergy; whereas seven items (11–17) measured their attitudes toward bioenergy on the IBPAMS (Table 3). Skewness and Kurtosis check for the individual items on the IBPAMS did not reveal any major skew in the data. The non-parametric Mann–Whitney U test was applied to reveal the effects of the gender and residence on each of the perceptions and attitude related items. Among the perceptions-related items, the students accepted the proposition that bioenergy could replace the fossil fuels in the future (item 2). The effects of both gender and residence appeared to be statistically significant related to this perception among the students. We found almost a near balance in opinions among the students related to a generally accepted positive attribute of bioenergy that increased use of it could solve the problem of global warming (item 1). About 38% of the students disagreed, while 36% of them accepted that proposition. Gender differences appeared to be statistically significant related to item 1 among the students while the effect of residence

Table 3 Students' responses to the International Bioenergy Perceptions and Attitudes Measurement Scale (IBPAMS)

Items	Acceptance (%)	DKn (%)	Rejection (%)	Mann Whitney *U* test (*p* values)	
				Gender	Residence
Perceptions					
1. Increased use of bioenergy can mitigate the global warming problems (*n*=1,885, *M*=2.93, S.D.=1.22, S.E.=0.03, Median=3)	36	26	**38**	0.00**	NS
2. Bioenergy can replace the use of fossil fuels in the future (*n*=1,885 *M*=3.07, S.D.=1.07, S.E.=0.02, Median=3)	**37**	33	30	0.01**	0.00**
3. Increasing bioenergy production will decrease food production (*n*=1,875, *M*=3.11, S.D.=0.87, S.E.=0.02, Median=3)	25	**56**	19	0.01**	0.01**
4. Wood energy will be a major source of bioenergy in the future (*n*=1,881, *M*=2.74, S.D.=0.91, S.E.=0.02, Median=3)	16	**47**	37	NS	NS
5. Production of energy from wood is environmentally friendly(*n*=1,886, *M*=2.44, S.D.=1.09, S.E.=0.02, Median=2)	19	21	**60**	NS	NS
6. Cutting trees for energy production is justified (*n*=1,885, *M*=2.53, S.D.=1.14, S.E.=0.03, Median=2)	23	25	**52**	NS	0.00**
7. Production of bioenergy from forests is globally sustainable (*n*=1,867, *M*=2.80, S.D.=1.07, S.E.=0.02, Median=3)	25	37	**38**	NS	NS
8. Tree plantations should be established for bioenergy production (*n*=1,886, *M*=3.05, S.D.=1.11, S.E.=0.03, Median=3)	33	**36**	31	0.00**	0.00**
9.There is growing awareness of bioenergy in society (*n*=1,880, *M*=3.16, S.D.=1.01, S.E.=0.02, Median=3)	34	**42**	24	NS	NS
10. Politicians should support the research and development of bioenergy in the society (*n*=1,881, *M*=3.12, S.D.=1.18, S.E.=0.03, Median=3)	34	**41**	25	0.00**	NS
Attitudes					
11. I would like to drive a car in the future that runs on biofuel (*n*=1,884, *M*=3.08, S.D.=1.20, S.E.=0.03, Median=3)	**37**	33	30	0.03*	NS
12. I would like to visit a bioenergy plant in my region (*n*=1,879, *M*=3.44, S.D.=1.08, S.E.=0.02, Median=3)	**44**	39	17	NS	NS
13. I would like to study more about bioenergy in the future (*n*=1,881, *M*=3.28, S.D.=1.03, S.E.=0.02, Median=3)	39	**41**	20	NS	NS
14. I would like to discuss bioenergy with my teachers (*n*=1,882, *M*=3.31, S.D.=1.03, S.E.=0.02, Median=3)	38	**44**	18	0.00**	NS
15. I would like to discuss bioenergy with my parents (*n*=1,882, *M*=3.26, S.D.=1.05, S.E.=0.02, Median=3)	34	**47**	19	0.00**	0.02*
16. I would like to discuss bioenergy with my classmates (*n*=1,884, *M*=3.39, S.D.=1.06, S.E.=0.02, Median=3)	40	**44**	16	0.00**	NS
17. I would like to use bioenergy at home in the future (*n*=1,880, *M*=3.17, S.D.=1.13, S.E.=0.03, Median=3)	**39**	37	24	NS	NS

Percentages in bold show the highest selection on an item

All percentages have been rounded off

Acceptance strongly agree plus agree, *DKn* do not know, *Rejection* strongly disagree plus disagree, *n* number of responses to each item, *M* mean value; *S.E.* standard error of the mean, *S.D.* standard deviation

*$p<0.05$; **$p<0.01$

was insignificant. Students' ambivalence appeared to be on the relationship between bioenergy and food security (Item 3) as 56% of them preferred not to take a clear position to the apparent controversial proposition that increasing bioenergy production would decrease food production. However, one fourth of the students voiced their concerns about the negative impacts of bioenergy on food production; whereas 19% did not endorse such concerns of their counterparts. Gender and residence both had statistically significant effects on students' perceptions of the proposition.

The state of ambivalence among the students also emerged in respect to the connection between wood as a source of modern bioenergy (item 4) as about 47% of them failed to take a clear stand related to this issue. Nevertheless, about 37% of the students rejected the important role of wood energy's share in the future bioenergy development. Gender and residence did not show any statistically significant effects among the students related to this topic. Apart from item 4, there were four other items, which measured the students' perceptions of the linkage between bioenergy from forests. About 60% of the students strongly rejected that energy

production from wood was environmentally friendly (item 5); similarly, 52% of the students did not support the justification for cutting trees for energy production (item 6) as they might have judged it inappropriate considering the link between biofuels and deforestation in tropical countries. The global issue of sustainable bioenergy production from forests was considered rather unsustainable by 38% of the students, while only one fourth of the students supported that notion (item 7). One third of the students endorsed their opinions in favor of tree plantations to be raised for bioenergy production (item 8), whereas 36% of them remained undecided. Both gender and residence showed statistically significant effects on students' perceptions related to this proposition. One third of the students were able to see the growing awareness of bioenergy in the society (item 9) and agreed that politicians should support bioenergy development (item 10). However, in both cases, majority of the students remained undecided as their answers fell into the do not know category.

A greater positive reflection of students' attitudes (items 11–17) than their perceptions of bioenergy emerged in this study. Nevertheless, in all the cases approximately one third of the students and in some cases half of them preferred to remain in the do not know category. The students were not only very positive on learning more about bioenergy from various sources such as school, home, local bioenergy plant, they also showed their willingness to use bioenergy (e.g., driving a biofuel car and using bioenergy at their homes).

T tests revealed statistically significant differences in gender (t=3.94, p<0.05) and residence (t=3.30, p<0.05) among the students about their overall perceptions (sum score of items 1–10) of bioenergy. In the study, boys and rural students were more critical than girls and urban students about their perceptions of bioenergy. In terms of overall attitudes (sum score of items 11–17) toward bioenergy, the study did not find any statistically significant differences in gender and residence. One-way ANOVA compared the countries with the scores of overall perceptions and attitudes related items on the IBPAMS. It revealed statistically significant differences with regard to perceptions ($F_{3,\ 1899}$=61.33, p<0.001) and attitudes ($F_{3,\ 1882}$=14.81, p<0.001) across the countries. Tukey post hoc comparisons with the countries indicated that in terms of students' overall perceptions of bioenergy, each country differed from the other in a statistically significant way (p<0.05). However, such statistically significant differences (p<0.05) related to students' attitudes toward bioenergy were only apparent between Finland–Taiwan, Taiwan–Turkey, and Finland–Slovakia.

In order to find out the relations between students' level of bioenergy knowledge and their perceptions and attitudes toward bioenergy, Crosstab and Chi-square tests were used. Students' level of bioenergy knowledge was further categorized into two subcategories: "basic" (comprising the "low" category) and "advanced" (comprising the "medium" and "high" categories) from Table 2. Similarly, students' overall perceptions and attitudes toward bioenergy were further categorized into four groups: very positive, positive, negative, and very negative. It appeared that the students with an "advanced" level of bioenergy knowledge demonstrated rather "negative" to "very negative" perceptions (Chi-square=13.45, df=3, p<0.05) and attitudes (Chi-square=9.27, df=3, p<0.05) toward bioenergy; whereas students with "basic" level of bioenergy knowledge did not take a very clear position related to bioenergy. This indicated a state of ambivalence among the students who lacked sufficient information about bioenergy compared to the "advanced" group. It was also revealed that students' "positive" to "very positive" perceptions of bioenergy corresponded to their "positive" to "very positive" attitudes toward bioenergy and vice versa (Chi-square=112.34, df=9, p<0.001).

Key Dimensions of Students' Perceptions and Attitudes Toward Bioenergy

PCA with pooled data from the four countries revealed three key dimensions of students' perceptions and attitudes toward bioenergy (Table 4), which explained 67% of the variation in the data. The items with dimension loading less than 0.50 were left out.

There was a "practical" dimension (α=0.86) which consisted of items that did not only identify the practical ways of using bioenergy in everyday life but also suggested the politicians to support the development of bioenergy. The other aspects of this dimension represented some elements of favor for bioenergy in displacing fossil fuels in the future; however, there were also elements of skepticism on the role of bioenergy in solving the problem of global warming. The "motivation" dimension (α=0.87) consisted of items that showed students' positive attitudes toward learning of bioenergy through different possible ways. The "critical" dimension (α=0.71) included items that raised doubts on the present methods of producing bioenergy from forests which were considered by many as unsustainable, not justified, and being environmentally unfriendly.

A one-way ANOVA measured the differences of dimensions in all four countries. In overall, the three dimensions differed significantly across the countries ("Practical": $F_{3,\ 1898}$=534.13, p<0.001; "Motivation": $F_{3,\ 1882}$=11.57, p<0.001; and "Critical": $F_{3,\ 1892}$=196.45, p<0.001). Tukey post hoc comparisons with these dimensions indicated that none of them were statistically significant between Finland and Turkey (p>0.05). The dimension "motivation" was not also statistically significant between Finland and Taiwan. In all other circumstances, the three dimensions differed in a statistically significant way between the countries (p<0.05). A reliability analysis was performed to measure the internal consistencies

Table 4 Key components of students' perceptions and attitudes related to bioenergy[a, b, c, d]

Key dimensions and items	Loadings on dimensions (those above 0.50 in bold)		
Practical			
I would like to use bioenergy at home in the future	**0.81**	0.17	−0.15
Increased use of bioenergy can mitigate the global warming problems	**0.79**	0.04	−0.07
Politicians should support research and development in bioenergy in the society	**0.79**	0.06	−0.11
Bioenergy can replace the use of oil and gas in the future	**0.79**	0.08	−0.10
I would like to drive a car in the future that runs on biofuel	**0.78**	0.12	−0.10
Motivation			
I would like to discuss more about bioenergy with my teachers	0.12	**0.87**	0.04
I would like to discuss more about bioenergy with my parents	−0.07	**0.87**	0.12
I would like to discuss more about bioenergy with my classmates	−0.14	**0.85**	0.10
I would like to study more about bioenergy in the future	0.32	**0.78**	0.01
I would like to visit a bioenergy plant in my region to know more about bioenergy	0.26	**0.68**	−0.11
Critical			
Production of energy from wood is environmentally friendly	−0.06	0.09	**0.81**
Cutting of trees for energy production is justified	−0.23	0.02	**0.79**
Production of bioenergy from forests is sustainable globally	−0.06	0.02	**0.75**

[a] Rotated components using Varimax

[b] Rotation converged in four iterations

[c] Kaiser–Myer–Olkin measure of sampling adequacy=0.84

[d] Bartlett's test of sphericity=<0.001

of the items under the three dimensions in all four countries (Table 5). The results showed moderate to high level of internal consistencies of the dimensions across the countries; however the internal consistency of the "critical" dimension was low in Turkey (α=0.45) and Slovakia (α=0.32). The reasons for the low internal consistencies for this "critical" dimension in Turkey and Slovakia are not clear from this study, thus results must be interpreted with caution.

Discussion

Two of the main objectives of this study were to investigate young students' level of knowledge, perceptions, and attitudes toward bioenergy in Finland, Taiwan, Turkey, and Slovakia; and reveal the effects of gender and residence on their knowledge, perceptions, and attitudes toward bioenergy. The study revealed that the majority of students in these four countries had a "low" to "medium" level of bioenergy knowledge including other REs and only a small percentage of them actually demonstrated a "high" level of bioenergy knowledge. This low level of bioenergy knowledge among public and pupils was also reflected in previous studies (see [3, 9, 22, 39, 79]). The Finnish students appeared to be the most knowledgeable in bioenergy especially in the "high" level category compared to the students in other three countries. In overall, there was no statistically significant difference between boys and girls and urban and rural students related to their level of bioenergy knowledge. Majority of the students rated their bioenergy knowledge as poor and this trend was more common among the girls than the boys. These patterns probably reflect stereotypically higher male-biased preferences for technologies (see [11, 52]). The deficiency in the "high" level of bioenergy knowledge among the students in this study can be attributed to the lack of topics related to REs in general and bioenergy in particular in the school curricula. Therefore, it indicates a need for discussing these topics in schools with practical examples.

In this study, a greater positive attitude toward bioenergy was apparent among the students compared to their perceptions of it. Not only had the students demonstrated positive attitudes toward bioenergy but also a positive

Table 5 Country wise internal consistencies of the key dimensions

Country	Practical (α)	Motivation (α)	Critical (α)
Finland	0.78	0.89	0.67
Taiwan	0.67	0.89	0.65
Turkey	0.84	0.89	0.45
Slovakia	0.53	0.83	0.32
Overall	0.86	0.87	0.71

willingness to use bioenergy at home and while driving cars. This positive relationship between attitudes and intended behavior in case of bioenergy differed from some other environmental attitude studies where such positive link between attitude and behavior was not revealed (see [57, 80]). This suggests that attitude guides behavior when a person is knowledgeable [16]. This study has also discovered that higher level of bioenergy knowledge among the students contributed to their criticism of bioenergy; whereas students with a lesser knowledge were ambivalent on the issue. In addition, students with positive perceptions of bioenergy also showed positive attitudes toward bioenergy. The study found both gender and residence effects on students' overall perceptions of bioenergy but not necessarily on their overall attitudes toward bioenergy. Boys and the rural students in general were more critical toward bioenergy than the girls and the urban students.

The third main objective of the study was to reveal the key dimensions of student's knowledge, perceptions, and attitudes toward bioenergy. The principal component analysis revealed three key dimensions of students' perceptions and attitudes toward bioenergy. The dimension "motivation" showed strong positive attitudes among the students toward learning more about bioenergy from various possible venues. The "critical" dimension revealed students' doubts and apprehensions toward bioenergy production from forests and the sustainability issues. The "practical" dimension among the students supported the use of bioenergy in their daily life; however, they were skeptical about the role of bioenergy in solving the problem of global warming. Although the countries included in this study are different from each other on several parameters, all of them are framing policies to fight against global climate change and taking up several measures especially in the field of energy from renewables. Substitution of biomass for fossil fuels in energy consumption is a measure to mitigate global climate change [91]. Finland is already an advanced country in modern bioenergy development and the other countries in our study are finding ways to introduce bioenergy. Therefore, from a policy point of view, the present study has been able to provide an important societal perspective on bioenergy regarding the younger generations.

Forest biomass for energy is considered to be in agreement with the principles of sustainable development [91]. In this study, the "critical" perceptions of students toward sustainability issues related to bioenergy production from forests could be attributed to two factors among many others. On one hand, their inadequate bioenergy knowledge did not help them to understand the complex concept of "sustainability" in the context of bioenergy production from forests. Due to this, they were either critical or ambivalent. On the other hand, the students who had more knowledge on bioenergy were considerably more critical of bioenergy including sustainability issues. Probably higher knowledge of the subject resulted in developing more doubts on the concept of sustainable bioenergy production. Previous research showed that students' level of knowledge increased their critical thinking skills [12, 41]. Utilization of forests in these four countries varies greatly from each other. Notwithstanding the fact that the modern bioenergy systems are more common in Finland than the other three countries, the Finnish students' critical perceptions of it did not differ from their counterparts in the other countries. This critical thinking toward complex technological developments such as bioenergy among young generations is relevant [39]. Critical thinking and knowledge construction might affect their perceptions, strengthen their positive attitudes, and change their behavior later in their life. Similarly, their motivation to know more about bioenergy is also a matter of encouragement for the educators, policy makers, and other professionals in the field of bioenergy. It will certainly help them to increase their comprehension of the subject and remove their state of ambivalence toward bioenergy to a greater extent. School science curriculum has to prepare students for their roles as future decision makers related to technologies, which will have a significant impact on the societies [17]. Modern bioenergy system is definitely such a technological development that will address the modern societies' clean and renewable energy needs for years to come.

Scientific literacy is an essential element of science education (see [37]). The OECD/PISA [70] framework comprises of three aspects of scientific literacy—scientific knowledge or concept, scientific processes, and situation or context. The science and technology component is part of the situation or context aspect, which includes use of energy among other issues (see [70] p. 139). In this context, there are opportunities to include more topics on REs in the course curriculum of young students in each country with practical examples of the related technologies. However, bioenergy-related education is both demanding and challenging. A major challenge for the teachers is to discuss the environmental and socioeconomic aspects related to bioenergy production and utilization. In addition, practical examples on bioenergy technologies might not be well developed in everywhere so that they are properly demonstrated to the students. Nevertheless, the challenges particularly in respect to technology demonstration should not restrict any ambition pertaining bioenergy-related education. Goodrum et al. [37] recognized the importance of technology as a curriculum item in school education; however, they did not suggest integrating both science and technology as part of it unless they would enhance learning of both. Role of the media is particularly important in this respect since the media can enhance the public's level of information about technological development

in bioenergy. Additionally, the media is the one that can publish both positive and negative images of bioenergy and influence the public perceptions and attitudes toward bioenergy. It is important for the students to know not only the positive aspects of bioenergy but also the challenges associated with its production and utilization. The role of media will be important on how it debates the challenges associated with bioenergy and biofuel production. The study presented an overall picture of students' knowledge, perceptions, and attitudes toward bioenergy from four countries, which are very different from each other on various socioeconomic, cultural, and environmental parameters. Therefore, in-depth country level analysis is needed to find out the latent factors for students' such knowledge, perceptions, and attitudes toward bioenergy.

Conclusions

The study revealed that the level of bioenergy knowledge among majority of young students in the four countries was "low" to "medium" although a small percentage of the students in each country demonstrated a "high" level of bioenergy knowledge. Young students' perceptions and attitudes toward bioenergy appeared to be multi-dimensional. Considering the socioeconomic and ecological differences across the countries in this study, such variations in students' perceptions and attitudes toward a new technological object such as modern bioenergy might be expected. The study was able to capture the dimensions of students' perceptions and attitudes toward bioenergy from an international perspective. Energy policies should aim for ensuring sufficient, reliable, and affordable energy supplies to support economic and social development, while protecting the environment [24]. The modern bioenergy in order to meet these criteria must be produced, converted, and used sustainably to demonstrate its environmental and socioeconomic benefits in comparison to fossil fuels [35]. A broader societal support is imperative for the success of bioenergy and young generation's positive attitudes on this matter is certainly important from the perspective of future bioenergy policies [40]. Future studies must go beyond classifying students' knowledge, perceptions, and attitudes toward bioenergy. They need to analyze the influencing factors in each country to reveal the characteristics of such psychological dimensions among the young students toward bioenergy. This will help both educators and energy policy makers to formulate country wise strategies for raising societal awareness of bioenergy and its introduction in the societies.

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