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# Knowledge, beliefs and attitudes of secondary school students on renewable feedstocks/biomass: the case of Greece

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**Abstract** Green Chemistry is a new approach of chemistry that aims to satisfy the global concerns and demand for sustainability. Green Chemistry is guided by twelve very specific principles of chemical practice. Among them, the seventh one promotes the use of renewable raw materials and feedstock, such as biomass. The widespread application of Green Chemistry principles in everyday life can be achieved by incorporating its paradigm into simple experiments and activities at regular school courses. Thus, an exploration of the students' background is required. The aim of this study is to provide baseline data on Greek student's knowledge, beliefs and attitudes related to the seventh Green Chemistry principle namely the use of renewable feedstocks, in order to facilitate introduction of appropriate provision in the school curricula and practice in Greece. Our results indicate that there is a serious knowledge gap among secondary school students regarding the main biomass formation mechanism and the connection of biomass to the global food supply in addition to the almost complete lack of knowledge of the main Green Chemistry principles. Regarding their attitudes, students are positive towards the use of biomass and express a very strong will to be environmentally informed. A logical conclusion of our research is that the development of relevant material that will focus on the application of Green Chemistry principles in everyday life in combination with a training of a core group of educators could be considered as the first steps towards the introduction of Green Chemistry principles in the secondary education system of Greece.

**Keywords** Sustainability · Biomass · Renewable resources · Green Chemistry · Education

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## 1 Introduction

Since the publication of the "Our common future" report (WCED 1987) and the Rio Summit in 1992, sustainable development has become the overarching political objective at global level for the implementation of which numerous innovative initiatives have been attempted in many scientific fields. As indicated in Chapter 36 of Agenda 21 (1992), appropriate multi and interdisciplinary education is needed. The Thessaloniki International Conference on Environment and Society: Education and Public Awareness for Sustainability (Scoullos 1998) that has promoted the idea of a strong shift to Education for Environment and Sustainability and the relevant Declaration clearly recommended the introduction and permeation of sustainability principles in all "sectoral educations". With the Johannesburg decision for enhanced efforts to promote sustainable development through systematic introduction and promotion of "Education for Sustainable Development" (ESD), the UN General Assembly (UNGA 2002) launched the "UN Decade for ESD (2005–2014)", and the 56 members states of the UN Economic Commission for Europe (UNECE 2005) elaborated through long participatory processes and adopted the "UNECE ESD Strategy" in Vilnius (Scoullos 2007). In both approaches, that is, either the permeation or the systematic promotion, it is emphasized that existing educational disciplines need to incorporate sustainability principles, tools and methods in order to contribute in reaching the goal of transformation of our production and consumption patterns towards sustainability. Clark (1999) declares that chemistry has a key role to play to achieving the societal, economic and environmental objectives of sustainable development. However, the same author identifies the fact that chemicals, chemistry and chemists are generally perceived by the wide public as causes of the environmental problems while their important role in providing solutions is not duly recognized. As Kirchhoff (2011) stated during the International Year of Chemistry 2011, in order to increase its public appreciation, chemistry has to play a key role in meeting the world needs. Therefore, in the context of chemistry-based applications of sciences, the future sustainable society will rely a lot on the supply and use of green and sustainable chemicals for the production of consumer goods that we use today and particularly those to be used in the future (Sikdar 2007). Green Chemistry is a new approach of chemistry that aims to satisfy the aforementioned global concerns and demand for sustainability through the design and application of chemical products and processes that efficiently utilize (preferably renewable) raw materials and reduce or eliminate the use and generation of hazardous substances (Anastas and Warner 1998). It is guided by twelve very specific principles of chemical practice. Among them, the seventh one promotes the use of renewable feedstocks, such as biomass, by stating that "a raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable".

Biomass is a renewable resource, formed by plants via photosynthesis, utilizing carbon dioxide and water as raw materials and sunlight as the energy source. Biomass is a source of carbon-based fuels and chemicals (Sheldon 2011). Several authors (Gallezot 2007; Manzer 2010; Metzger and Eissen 2004; Naik et al. 2010; Petrus and Noordermeer 2006; Sharma et al. 2011; van Haveren et al. 2007) have reviewed biomass-based products, such as liquid and gaseous fuels and platform molecules that can be employed as building blocks in the synthesis of chemicals and polymeric materials. The environmental advantages deriving from the utilization of biomass result from the biomass cycle itself. Biomass-based products can, in principle, be biologically degraded at the end of their life cycle into carbon dioxide and water, ideally producing no "additional" carbon dioxide since the amount of carbon dioxide released at the end of the life cycle of the plant is identical to the respective captured during the photosynthesis of the plant. In real life, some fossil fuel energy is usually required for the processing of biomass feedstocks to useful products. Therefore, the carbon dioxide balance is not completely neutral. It is also noteworthy that although the chemical energy embodied in the biomass-based products comes mainly from the sun, modern cultivations involve also chemical fertilizers and other agrochemicals as well as non-renewable energy inputs for agricultural machinery, irrigation, transports, etc., which need to be included in a proper "footprint" calculation of biomass production (Horizon 2020 Initiative 2011).

Gallezot (2007) claims that the use of biomass for the production of energy, chemicals and materials is one of the key solutions in approaching sustainable development while Metzger and Eissen (2004) declare that "renewables are the only workable solution, and their processing…will make it possible to replace oil and coal". Van Haveren et al. (2007) suggested that biomass-based products are expected to make a significant impact on the production of bulk chemicals within the next 10 years, and they may have huge impact within the next 20–30 years. To achieve this, the aforementioned negative side effects of biomass production and use need to be properly addressed. Sheldon (2011) concludes that in order to be sustainable, biomass production and utilization will depend heavily on the successful deployment of the innovative, Green Chemistry.

From the aforementioned introduction, it is evident that for the widespread utilization of renewable feedstocks in everyday life, education and training is required especially at the research/academic and industrial sectors. However, a much more wide awareness and education are needed throughout the society in order to reach the necessary consensus and make the shift in mindsets and attitudes. This can be achieved to a large extend, by incorporating the appropriate principles and paradigms into basic formal education through simple experiments and activities in the regular school curricula. On the question "how can Green Chemistry be communicated in demonstration lectures to large school audiences" Leimer (2004) suggests by concentrating on specific key issues in depth rather than to try to cover thinly too many aspects at one time. For such an approach, an exploration of the students' background was necessary.

Therefore, the aim of the present study is to provide baseline data on Greek student's knowledge, beliefs and attitudes related to the seventh Green Chemistry principle, that is, the use of renewable feedstocks/biomass. More specifically, this research focuses on:

- Recording students' knowledge on renewable feedstocks/biomass.
- Detecting students' beliefs about renewable resources/biomass.
- Examining students' attitudes in using everyday consumers' products.
- Determining the influence of certain sociodemographic parameters related to the background of the students (gender, parents' educational background, residence area or previous participation in environmental education activities) on their knowledge, beliefs and attitudes.

Considering the fact that the time allocated for chemistry teaching in Greece is very limited in the secondary school curriculum—a condition which is not likely to be changed soon—emphasis has to be placed on the introduction of Green Chemistry and the relevant sustainable development principles through their diffusion in all relevant school courses/disciplines such as chemistry, biology, environmental education, etc. Thus, the results of this research can be used for the design of educational interventions that focus on the introduction of the principles of renewable raw materials utilization at the secondary school level. In that way, students will become aware about the main principles and applications of Green Chemistry essential for their everyday life.

The investigation of students' knowledge, beliefs and attitudes towards several environmental issues has been an active area of research for the science education community for many years. Till now, the majority of the existing studies focused on several environmental issues such as climate change, ozone depletion, waste management or air pollution, etc. (Boyes et al. 1999; Liarakou et al. 2011; Lin and Hu 2003; Meneses and Palacio 2005; Rye et al. 1997; Skamp et al. 2004). As the field of Green Chemistry is a still developing one, there is a scarcity of published research into Green Chemistry education on the secondary education level. To the best of our knowledge, this is the first study in Greece which examines students' knowledge, beliefs and attitudes towards the use of biomass renewable raw materials.

## 2 Methodology

Data for the current research were obtained from 414 secondary school students at the 8th and 9th grades, attending 12 typical secondary schools situated in urban and suburban areas of Greece. The research took place during the second semester of the school year 2009–2010 and was conducted during the chemistry class hours. Eleven public schools and one private were selected to participate in this study. The selected schools are classified into two categories: "urban" from the greater urban metropolitan area of Athens (7 schools) and "suburban" from small towns and villages in periphery regions of Greece in the prefectures of Achaia, Andros and Thesprotia (5 schools). Detailed information about the research's sample is presented in Table 1.

Data were collected via an anonymous closed-type questionnaire. The limited time assigned for chemistry courses in the Greek schools, as well as the overall context of the Greek curriculum, was considered during the construction of the questionnaire that was further reviewed by a panel of three experts. To ensure the "comprehensibility" of the content by the students and its reliability, a pilot study was conducted using fifty-six students, attending the 8th and 9th grades in a school in the urban Athens area, as the target group. During the pilot study, the time required for the questionnaire's completion varied between 12 and 23 min. The questionnaire consisted of four sections:

The *first* section included fixed-type questions on demographic, social and past activity characteristics of the participants, such as gender, parent's educational background and previous participation in environmental education activities.

In the *second* section, nine multiple choice questions were included which aimed to assess students' knowledge about renewable feedstocks/biomass and their utilization in the context of Green Chemistry. More specifically, students were asked about Green Chemistry and its basic principles, the process of renewable resources formation, their advantages compared to fossil fuel resources, their impacts in terms of their production and improper use. Moreover, students were asked to recognize some petrochemical products as

**Table 1** Analysis of students' sample per gender and school location

| | Athens metropolitan area | Suburban areas | Total (*N*) | Total (%) |
|---|---|---|---|---|
| Boys | 124 | 93 | 217 | 52.4 |
| Girls | 99 | 98 | 197 | 47.6 |
| Total (*N*) | 223 | 191 | 414 | |
| Total (%) | 53.9 | 46.1 | | 100.0 |

well as some products that can be produced from renewable raw materials. Five of those questions had just a single correct answer while four of them had more than one. Each question was scored in such a way that "1" represented the correct answer while "0" represented a false answer (Bartholomew et al. 2002). The answer "do not know" was also scored as "0" (Kuhlemeier et al. 1999). In the questions with more than one correct answer, "1" was divided among the correct answers. Thus, if a student selected all the correct answers, the total score for this question was still 1. The sum of all nine knowledge questions made up the knowledge scale of our research, which ranged from 0 (min) to 9 (max).

The *third* section consisted of 14 statements which aimed to assess students' beliefs, while the *fourth* included 4 statements which aimed to assess students' attitudes towards the seventh principle of Green Chemistry, that is, the use of renewable raw materials. The participants were asked to respond with a five-point Likert-type scale (1 corresponds to disagree, 2 to rather disagree, 3 to neither agree nor disagree, 4 to rather agree and 5 corresponds to agree). Negative expressed statements were scored in reverse order. The sum of all 14 beliefs questions made up the beliefs scale of our research, ranging from 14 (min) to 70 (max), while the attitudes scale ranged from 4 (min) to 20 (max).

For the purposes of our research, we follow the nomenclature introduced by Newhouse (1991): attitudes are defined as the enduring positive or negative feeling about some person, object or issue. Closely related to attitudes are beliefs, which refer to the information (the knowledge) a person has about a person, object or issue (Newhouse 1991). Based on the above-mentioned written definitions of Green Chemistry, renewable raw materials and biodegradation were provided as an introduction to the third and fourth sections of the questionnaire. Students were asked to complete separately the second from the third and fourth parts of the questionnaire in order to avoid being biased by the definitions given.

Cronbach's Alpha values for the third and fourth parts of the questionnaire were found to be 0.714 and 0.708, respectively, both exceeding 0.7, which indicates appropriate reliability of both scales.

## 2.1 Data analysis procedure

The completed questionnaires were analysed by using inferential statistical analysis of the research questions of the study. SPSS version 19.0 statistical program was used to analyse and calculate the scores. The 5 % significance level ($p < 0.05$) was selected as the breakpoint for our analysis.

Concerning the variables of gender (boy or girl), residence area (urban or suburban) and previous participation in environmental education activities (yes or no), the mean scores of students' responses for the knowledge, belief and attitudes scales were calculated. Independent samples $t$ tests were conducted to determine whether there were significant differences among the mean scores of the variables examined. Concerning the parents' educational background, data were collected and then recoded to two groups: the first one includes those parents who have completed just the 9 years of compulsory education in Greece. The second group includes those parents who received education beyond the compulsory. In this group, parents who hold a university or higher degree are included. Based on the two parents' groups, independent samples $t$ test was conducted again to check the influence of parents' education on the students' knowledge, beliefs and attitudes.

## 3 Results

Table 2 presents the mean values for the knowledge questions; Table 3 includes the percentages and mean values for the beliefs of the students, while Table 4 presents the respective mean values for the attitudes. Following is a detailed analysis of students' knowledge, beliefs and attitudes.

### 3.1 Students' knowledge on renewable feedstocks/biomass

58.9 % of the students recognized, crude oil among other materials, such as organic municipal waste, agricultural residues, livestock waste as non-renewable feedstocks, while almost 18 % choose "I don't know" (see Table 2). With respect to the question about the main "formation" process of biomass, 33.8 % stated "I don't know", while 37.7 % choose "refining", "evaporation" or "extraction" as the main formation process. Only 28.5 % of the students identified correctly photosynthesis as the main "formation" process.

Regarding the question for the advantages of renewable raw materials, it is remarkable that only 2.1 % of the students selected all of them. As advantages of the renewable raw materials, students primarily recognized the reduction in dependence on fossil fuels (46.1 %) and at an equivalent percentage the reduction in greenhouse gases emissions. The highly debatable reinforcement of rural areas economy and the potential use of organic waste were recognized as advantages, by only 21.3 and 25.6 % of the students, respectively.

With respect to the question "Which of the following is not considered as a Green Chemistry's principle", about half of the students (44.9 %) answered "I do not know", while a low percentage (of 14.5 %) of students recognized that the waste treatment at the end of a chemical process is not a principle of Green Chemistry. Of the respondents, 63.5 % considered that Green Chemistry is not a "religious doctrine", while the remaining 36.4 % noted the other options including the option "I do not know".

Among the environmental management hierarchy options, most of the students (65 %) considered recycling as the most appropriate way to protect the environment, while only 21.7 % choose the "proper" answer, which is "pollution prevention".

Students have been asked to recognize, among a list, the petrochemical products. It is striking that only 3.4 % of students recognized them all. Although 84.5 and 69.1 % of the respondents recognized, respectively, transportation fuels and plastic bags, as petrochemical products, detergents and insecticides have been recognized as petrochemical products by only 22.9 and 19.6 % of the respondents, respectively.

To the question "Which of the following products can be made from renewable raw materials? (Mark all that you know)", it is interesting that only 2.7 % of the students noted that all products included can be made from renewable raw materials. It is noteworthy that 31.9 % of the students claimed that they do not know any product that can be made from renewable raw materials. Of the students, 76.8 % did not select fuels as a product that can be made from renewable raw materials, 68.6 % did not select the adhesives, while 72.9 % did not select the detergents.

Finally, only 5.8 % of the students marked all the impacts of renewable raw materials resulting from their production or improper use, while one in three students could not recognize any of those impacts. Most of the students recognized the destruction of ecosystems (64 %), while 37.2 % recognized the negative impact on the biodiversity. Only 19.6 % of the students checked that "the reduction of food supply could be an impact resulting from the uncontrolled production of renewable raw materials".

**Table 2** Students' knowledge on renewable feedstocks/biomass

| Knowledge question | Mean | SD |
|---|---|---|
| Which of the following is not a renewable feedstock? (single correct answer) | 0.59 | 0.49 |
| Forest residues | | |
| Crude oil | | |
| Organic municipal waste | | |
| Agricultural residues | | |
| Livestock waste | | |
| I do not know | | |
| The advantages of renewable feedstocks compared to fossil are…: (multiple correct answers) | 0.35 | 0.25 |
| The reduction in dependency on fossil fuels | | |
| The ability to utilize organic waste forms | | |
| The reduction in greenhouse gases emissions | | |
| The economic empowerment of rural areas | | |
| I do not know | | |
| The main process for the formation of renewable feedstocks is…: (single correct answer) | 0.29 | 0.45 |
| Photosynthesis | | |
| Mining | | |
| Distillation | | |
| Evaporation | | |
| I do not know | | |
| Which of the following is not a principle of Green Chemistry? (single correct answer) | 0.14 | 0.35 |
| Design of products for biodegradation | | |
| Safety during a chemical process | | |
| Waste treatment at the end of a chemical process | | |
| Use of renewable feedstocks | | |
| Pollution prevention | | |
| I do not know | | |
| What is not Green Chemistry? (single correct answer) | 0.64 | 0.48 |
| The branch of chemistry that deals with forests protection | | |
| The environmental friendly chemistry | | |
| The branch of chemistry that deals with materials recycling | | |
| A religious doctrine (or a religious dogma or a religious belief) | | |
| I do not know | | |
| Among the following, which is the most preferable option for the protection of the environment? (single correct answer) | 0.22 | 0.41 |
| Waste treatment | | |
| Recycling | | |
| Pollution prevention | | |
| I do not know | | |
| Which of the following are products of crude oil? (multiple correct answers) | 0.49 | 0.21 |
| Plastic bags | | |

**Table 2** continued

| Knowledge question | Mean | SD |
|---|---|---|
| Insecticides | | |
| Automotive fuels | | |
| Detergents and cleaning products | | |
| I do not know | | |
| Which of the following are products of renewable feedstocks? (multiple correct answers) | 0.31 | 0.26 |
| Automotive fuels | | |
| Adhesives and glues | | |
| Plastics | | |
| Cleaning products | | |
| I do not know | | |
| Improper utilization of renewable feedstocks can result in… (multiple correct answers) | 0.40 | 0.30 |
| Ecosystems destruction | | |
| Biodiversity reduction | | |
| Reduction of food supply | | |
| I do not know | | |

### 3.2 Students' beliefs on renewable feedstocks/biomass

In order to improve the clarity of our results, we use the term "agree" in the following pages to denote the inclusion of both "agree" and "rather agree" results presented in Tables 3 and 4. Likewise, the term "disagree" encompasses both the "disagree" and "rather disagree" results of Tables 3 and 4.

Six statements were included in the questionnaires that were dealing with students' beliefs on everyday products made from renewable raw materials. Although one could always argue that the answers could have been guided by knowledge rather than belief the fact that the students had clearly very little knowledge and information on the issue justifies this classification. The selection of the products was based on their citation in recent literature (Gallezot 2007; Manzer 2010; Metzger and Eissen 2004; Naik et al. 2010; Petrus and Noordermeer 2006; Sharma et al. 2011; van Haveren et al. 2007). Based on the mean values presented in Table 3, the production of soap from olive oil seems to be quite known ($M = 3.87$) followed by the production of detergents from plant matter ($M = 3.28$). For the remaining products, students' selections scored below 3, that is, students hardly perceived the existence of processes that generate those products from renewable sources. The generation of transportation fuel from cooking oil scored $M = 2.76$, the generation of glue from milk scored $M = 2.44$, while the production of plastic bags from potato or corn scored $M = 2.27$. Finally, the production of transportation fuel from sugar is the least perceived one ($M = 2.23$). Moreover, 80 % agreed that buying products made from renewable raw materials contributes to the environmental protection ($M = 4.14$), which is ranked first among the expressed beliefs. At the same time, a significant proportion (42 %) of the students consider that a product made from renewable raw materials is of a lower quality than a corresponding one made from fossil resources ($M = 2.60$).

**Table 3** Students' beliefs on renewable feedstocks/biomass

| Statement | Agree (%) | Rather agree (%) | Neither agree nor disagree (%) | Rather disagree (%) | Disagree (%) | Mean | SD |
|---|---|---|---|---|---|---|---|
| 1. By buying consumer products made from renewable raw materials, we support the protection of the environment | 43.7 | 37.4 | 10.6 | 5.1 | 3.2 | 4.14 | 1.00 |
| 2. The use of products made from renewable raw materials does not harm the environment | 8.0 | 14.0 | 21.5 | 34.3 | 22.2 | 3.49 | 1.21 |
| 3. It is possible to produce fuel using spent cooking oil as raw material | 11.8 | 18.8 | 26.1 | 19.8 | 23.4 | 2.76 | 1.32 |
| 4. It is possible to produce a plastic bag from corn or potato | 4.8 | 9.4 | 29.5 | 20.5 | 35.7 | 2.27 | 1.18 |
| 5. The contribution of chemical industry in environmental pollution is large | 46.1 | 31.6 | 14.5 | 3.6 | 4.1 | 4.12 | 1.05 |
| 6. A consumer product made from renewable raw materials is of lower quality compared with a respective one made from fossil materials | 27.8 | 13.8 | 36.2 | 14.7 | 7.5 | 2.60 | 1.24 |
| 7. The uncontrolled utilization of renewable biomass materials may result in the degradation of natural ecosystems | 20.5 | 25.1 | 27.3 | 14.3 | 12.8 | 3.26 | 1.29 |
| 8. The role of Green Chemistry in environmental protection is important | 47.8 | 24.2 | 21.0 | 4.1 | 2.9 | 4.10 | 1.05 |
| 9. It is possible to produce soap using oils from olive or palm trees as raw materials | 34.8 | 34.1 | 19.3 | 7.0 | 4.8 | 3.87 | 1.11 |
| 10. It is possible to produce glue using milk as raw material | 3.6 | 8.5 | 40.3 | 23.7 | 23.9 | 2.44 | 1.06 |
| 11. Green Chemistry aims at the improvement of chemical products for the sake of environmental protection | 32.4 | 29.7 | 27.3 | 5.1 | 5.6 | 3.78 | 1.12 |
| 12. It is possible to produce transportation fuel using sugar as raw material | 3.4 | 7.5 | 29.5 | 28.0 | 31.6 | 2.23 | 1.08 |
| 13. An informed citizen is an active citizen | 37.0 | 35.7 | 16.2 | 5.8 | 5.3 | 3.93 | 1.11 |
| 14. It is possible to produce detergents using plant matter as raw material | 17.4 | 30.4 | 24.9 | 16.9 | 10.4 | 3.28 | 1.23 |

**Table 4** Students' attitudes on renewable feedstocks/biomass

| Statement | Agree (%) | Rather agree (%) | Neither agree nor disagree (%) | Rather disagree (%) | Disagree (%) | Mean | SD |
|---|---|---|---|---|---|---|---|
| 1. When buying a consumer product we should check whether it is made from renewable raw materials | 21.0 | 27.5 | 35.3 | 10.6 | 5.6 | 3.48 | 1.10 |
| 2. When buying a consumer product we should check whether it is biodegradable | 19.1 | 25.1 | 35.3 | 11.4 | 9.2 | 3.34 | 1.18 |
| 3. I wish to be informed via any possible way (e.g. school, internet, mass media) for consumer products that are environmentally friendlier | 54.1 | 27.3 | 10.9 | 4.1 | 3.6 | 4.24 | 1.04 |
| 4. I support environmental protection through my consumer choices | 39.9 | 31.6 | 17.9 | 5.3 | 5.3 | 3.95 | 1.13 |

Regarding the relationship of the chemical industry and the environment, 77 % of the students agree that the chemical industry has a large contribution in the environmental pollution ($M = 4.12$). On the other hand, an equal percentage of the students (approx. 70 %) agree that Green Chemistry could play an important role towards environmental protection ($M = 4.10$). Moreover, almost 60 % of the students agree that Green Chemistry aims at the improvement of chemical products for the sake of environmental protection ($M = 3.78$). Regarding the impacts resulting from the utilization of renewable materials, 56 % of the students seemed to believe that the use of products made of those materials does not harm the environment ($M = 3.49$), while 45 % agreed that the uncontrolled production of renewable raw materials can lead to the destruction of ecosystems ($M = 3.26$).

### 3.3 Students' attitudes on renewable feedstocks/biomass

Focusing now on the attitudes (see Table 4), despite ignorance, hesitations and misconceptions about specific issues as we observed from the first part of the questionnaire, it is noteworthy that approximately 70 % of the students agreed that their consumer choices can protect the environment ($M = 3.95$). Moreover, almost half of the students agreed that when buying a product they should think whether it is made from renewable raw materials ($M = 3.48$), while 45 % agreed that they should consider whether it is biodegradable ($M = 3.34$). All of them constitute very positive attitudes. Finally, most of the students (80 %) are positive to be informed about environmentally friendly consumer products via any possible means ($M = 4.24$). This is the strongest expressed attitude among all students.

### 3.4 The effect of sociodemographic characteristics on students' knowledge, beliefs and attitudes

In order to check the effect of the sociodemographic characteristics, scores in knowledge, beliefs and attitudes were treated as three distinct dependent variables, while gender, residence area, parents' educational background and previous participation in environmental education projects were the independent ones. Consequently, students' knowledge, beliefs and attitudes were assessed to find out whether and how they are affected by those independent variables.

Independent samples $t$ tests were conducted to compare the knowledge, beliefs and attitudes scores for boys and girls. There was a significant difference in knowledge score for boys ($M = 3.23$, $SD = 1.46$) and girls ($M = 3.63$, $SD = 1.54$; $t(412) = -2.680$; $p = 0.008$) meaning that the knowledge of girls is better than the respective of the boys. The same pattern was also observed for beliefs for boys ($M = 45.30$, $SD = 6.37$) and girls ($M = 47.35$, $SD = 6.56$; $t(411) = -3.21$; $p = 0.001$) and for attitudes for boys ($M = 14.46$, $SD = 2.78$) and girls ($M = 15.61$, $SD = 2.83$; $t(411) = -4.18$; $p = 0.000$). The magnitude of the differences in the means for knowledge, beliefs and attitudes was small ($\eta^2$: 0.017, 0.024 and 0.041, respectively).

The next variable examined was the "previous participation of student in environmental education activities". There was significant difference in knowledge score for those that participated ($M = 3.83$, $SD = 1.37$) and those that did not ($M = 3.11$, $SD = 1.54$; $t(412) = 4.981$; $p = 0.000$) meaning that those who participated in environmental education activities had better knowledge that those who did not. The magnitude of the differences in the means of knowledge was moderate ($\eta^2 = 0.057$). There was also significant difference in beliefs score for those that had previously participated in environmental education activities ($M = 47.24$, $SD = 6.42$) and those who did not ($M = 45.54$, $SD = 6.54$; $t(411) = 2.64$; $p = 0.009$). The magnitude of the differences in the means of beliefs was small ($\eta^2 = 0.017$). Finally for attitudes, there was also significant difference in the score for those that had previously participated in environmental education activities ($M = 15.56$, $SD = 2.60$) and those who did not ($M = 14.60$, $SD = 2.98$; $t(411) = 3.49$; $p = 0.001$). The magnitude of the differences in the means of attitudes was small ($\eta^2 = 0.029$).

The influence of the school location and therefore the residence background (urban or suburban) of the students on their knowledge and beliefs was also examined. There was significant difference in knowledge score between those that live and study in an urban location ($M = 3.64$, $SD = 1.59$) and those that do not ($M = 3.17$, $SD = 1.37$; $t(412) = 3.254$; $p = 0.001$). The magnitude of the differences in the means of knowledge was small ($\eta^2 = 0.025$). However, there was no significant difference in the beliefs score ($M = 46.69$, $SD = 6.80$ for urban) and ($M = 45.79$, $SD = 6.18$; $t(411) = 1.402$; $p = 0.162$ for suburban) or in the attitudes score ($M = 15.17$, $SD = 2.80$ for urban) and ($M = 14.82$, $SD = 2.93$; $t(412) = 1.238$; $p = 0.217$ for suburban) between the two groups for urban and suburban school location, respectively.

Finally, the influence of parents' educational backgrounds on students' knowledge was significant. Students whose fathers had a higher educational background level ($M = 3.54$, $SD = 1.55$) had better knowledge compared with those with a lower one ($M = 3.03$, $SD = 1.29$; $t(412) = -3.247$; $p = 0.001$). Similarly, significant difference in knowledge was observed for those that had mothers with higher educational background level ($M = 3.55$, $SD = 1.54$) and those who did not ($M = 2.96$, $SD = 1.29$; $t(412) = -3.709$; $p = 0.001$). The magnitude of the differences in the means of knowledge was small in both cases ($\eta^2 = 0{,}025$ for fathers, $\eta^2 = 0.032$ for mothers).

However, the parents' educational backgrounds, for both father [$t(411) = -1.242$, $p = 0.215$] and mother [$t(411) = -1.802$, $p = 0.072$] do not have a significant effect on their children' beliefs towards renewable raw materials. Moreover, the educational background of the father [$t(411) = 0.02$; $p = 0.999$] or mother [$t(411) = 0.415$; $p = 0.678$] does not have a significant effect on the children' attitudes.

## 4 Discussion

The first important finding is that most of the students recognize crude oil as being a non-renewable resource. This is rather expected since crude oil and the environmental impacts associated with its extraction and use are well known. Moving on to the renewable raw materials, one in three students does not know the basic mechanism for biomass production, and only one in four replied correctly about the role of photosynthesis. Both of these results indicate the low degree of knowledge of the students with respect to biomass. The knowledge of students regarding Green Chemistry, explored in a couple of questions, was considerably low. This is expected since Green Chemistry principles have not been introduced systematically in the secondary school curricula of Greece. More than 6 out of 10 students choose recycling, among the given options, as the most appropriate way to protect the environment while only one in five recognized "pollution prevention" as the preferable option. This outcome was also, more or less, expected since recycling is very popular among the environmental education themes in secondary schools and is promoted by TV and press in contrast to "pollution prevention" which is practically rarely referred as an environmentally friendly option, probably because it contradicts to the prevailing consumption patterns of our societies.

Considering the petrochemical products, less than 5 % of the students could recognize, correctly, all of them. The most recognizable are transportation fuels and plastic bags. On the contrary, detergents and insecticides were the least recognizable. Again, this may be attributed to knowledge obtained informally. Thus, we have the contradictory result that students know the crude oil but do not recognize its products. The main implication from these results is that students lack basic knowledge regarding the origin and transformation of raw materials that yield to common everyday products. Most importantly, the students cannot relate those products to environmental impacts, since they cannot recognize even the starting raw materials.

Most of the students could not recognize even a single product deriving from bio-based raw materials, while the destruction of ecosystems was the most recognizable eventual negative impact associated with them. Interestingly enough, only one in five students associated biomass utilization to food supply. Clearly, there is a knowledge gap of the students regarding biomass and biomass-derived products, even for those products that are associated with food for humans. This result, although disturbing, is typical for westernized societies: as Ehrlich (2011) states, "even the educated people in developed countries think that their food is coming from the supermarket". Even though knowledge is just a single, among many others factors that yield to pro-environmental behaviour (Kollmuss and Agyeman 2002), our results indicate that educational interventions should be planned and executed aiming at improving the knowledge level of the Greek students. As Jensen (2002) states "a participatory and action-oriented form of environmental education does not rule out basic knowledge and insight".

Regarding their reported beliefs, students feel very strongly that the chemical industry has a large contribution to environmental pollution. However, they also recognize the positive impact that Green Chemistry could have towards environmental protection. Taking also into account the low degree of knowledge regarding Green Chemistry reported by the students, this result may imply the tension of students to answer in a particular way so as to satisfy the teacher or the researcher. In addition, almost eight out of ten students have a positive attitude towards the diffusion of environmental knowledge. This is also supported by their belief according to which appropriate consumer choices can protect the environment. More than half of the students expressed right beliefs about biomass-based raw materials and their potential towards environmental protection. They also recognize biodegradability as a significant property that enhances environmental friendliness of consumer products.

On the effect of sociodemographic characteristics, the present research indicates that the mean score of girls' knowledge is significantly higher than that of boys; their beliefs are more right, and their attitudes are also significantly more positive than those of boys. Similar results concerning attitudes on environmental issues, in general, have been reported by Aho et al. (1989), Connell et al. (1999), Eagles and Demare (1999), Tikka et al. (2000) and Alp et al. (2008). The aforementioned authors concluded that girls demonstrated more positive attitudes for the environment and have more interest and sensitivity about environmental issues compared with boys.

Students who participated, even once before, in environmental education activities had significantly higher level of knowledge and expressed more positive attitudes compared with those who did not. Furthermore, related research has shown that students attending environmental education activities have higher awareness about environmental concepts (Barraza and Walford 2002). Similarly, a previous research among Greek students resulted that students participating in environmental education activities demonstrated more friendly attitudes towards the environment (Trikaliti 1995), although this is not always the case (Papadopoulos 2005).

The results indicate that those students living and studying in urban areas have significantly higher level of knowledge for this specific topic than students from suburban areas. Concerning students' beliefs and attitudes, analysis of $t$ test showed no statistically significant difference between the two groups. Looking into the literature, several results were found related to the impact of residence on students' attitudes towards environment. Worsley and Skrzypiec (1998) claim that all students originating either from urban or rural areas appear rather pessimistic about the environment. On the other hand, in a survey conducted in Turkey (Yilmaz et al. 2004), it is reported that students with high family incomes coming from urban areas have more correct beliefs for environmental issues than students of low family income, coming from suburban areas.

The important role of family in the development of positive environmental attitudes of young people has been emphasized by various authors (Connell et al. 1999; Loughland et al. 2003). One of the most influential factors for the development of positive environmental attitudes is the educational background of parents. The higher educational level leads, in general, to systematic pedagogic actions (mainly relevant behaviours) raising environmental awareness in children (Abeliotis et al. 2010). Payne (2005) highlighted the educational role of parents at Australian families. Gambro and Switzky (1999) reported that the educational background of parents influences the knowledge of students regarding pollution and energy consumption. Similar results have been reported by many other researchers (Hampel et al. 1996; Kuhlemeier et al. 1999).

In earlier studies, Zimmermann (1996) reported that students with high cognitive level had more positive environmental attitudes. This is consistent with the traditional thinking among educators and many environmental education theorists that identify positive relationships between environmental knowledge, beliefs and behaviour. In other words, as Scoullos and Malotidi (2004) suggest, there is a widespread acknowledgement of a positive attitude towards the environment and the associated behaviour which could be, at least partly, the result of increased environmental knowledge. However, currently, it is widely accepted that environmental knowledge is, by no means, sufficient to yield to environmentally friendly behaviour as discussed by various authors (Ehrlich 2011; Jensen 2002; Kollmuss and Agyeman 2002).

Beliefs, attitudes and behaviours are influenced also by many other factors (Kollmuss and Agyeman 2002). For instance, the interpretation of the results of the present study takes into account not the knowledge itself but the method in which relevant knowledge is provided to the students in the context of the existing chemistry curriculum in Greece. Students have their first contact with chemistry at the age of 13; at grades 8 and 9, all students study chemistry as a distinct core course but only for 1 h per week. At these levels, chemistry curriculum follows a "macroscopic to microscopic" approach (Salta and Tzougraki 2004). Green Chemistry concepts are completely missing from this curriculum. In our opinion, the introduction of Green Chemistry concepts should be a principal goal in any modern science curriculum due to the increasing role of chemistry in economy and the citizens' daily lives. Besides that, one of the general principles of education in Greece, as it is explicitly required in the "national cross thematic curriculum framework" for secondary education but also in the adopted by Greece UNECE Strategy for Education for Sustainable Development is for the students to develop environmental awareness and foster relevant patterns of behaviour contributing to sustainable development.

## 5 Conclusions

The present work focuses—for the first time in Greece—on the knowledge, beliefs and attitudes of secondary school students on the utilization of renewable raw materials with a special focus on biomass. Our results indicate that there is a serious knowledge gap, even many misconceptions among the secondary school students regarding the main biomass formation mechanism, the connection of biomass production and use to the global food supply and almost complete lack of knowledge of the main Green Chemistry principles.

Regarding their attitudes, students are positive towards biomass utilization and express a very strong will to be better informed in environmental issues. On the effect of sociodemographic characteristics, girls have better knowledge and more positive attitudes compared with boys; the impact of participation in environmental education activities in earlier years is positive for both knowledge and beliefs; students who live and study in urban settlements have better knowledge than those who live in suburban areas while there is a positive impact of the educational background of parents on both knowledge and beliefs of the students.

Based on the aforementioned conclusions, the absence of a systematic framework for the introduction of Green Chemistry in secondary education in Greece is revealed. The first step towards this goal could be the development of relevant educational material that focuses on the application of Green Chemistry principles in everyday life.

In our opinion, the goals of the introduction of Green Chemistry principles in the secondary school curriculum has to lead to (a) the formation of a basic conceptual context for Green Chemistry; (b) the proper comprehension of Green Chemistry's potential contribution to global sustainability and food supply; (c) the demonstration of the link of Green Chemistry with everyday life; (d) the enhancement of motives and personal commitment of students to become active citizens and responsible consumers.

## References


Abeliotis, K., Goussia-Rizou, M., Sdrali, D., & Vassiloudis, I. (2010). How parents report their environmental attitudes: A case study from Greece. *Environment, Development and Sustainability, 12*, 329–339.

Aho, L., Permikangas, T., & Lyra, S. (1989). Finnish primary school children's preferences in environmental problem solving. *Science Education, 73*(5), 635–642.

Alp, E., Ertepinar, H., Tekkaya, C., & Yilmaz, A. (2008). A survey on Turkish elementary school students' environmental friendly behaviours and associated variables. *Environmental Education Research, 14*(2), 129–143.

Anastas, P., & Warner, C. J. (1998). *Green chemistry: Theory and practice*. New York: Oxford University Press.

Barraza, L., & Walford, R. A. (2002). Environmental education: A comparison between English and Mexican school children. *Environmental Education Research, 8*(2), 171–186.

Bartholomew, D. J., Steele, F., Moustaki, I., & Galbraith, I. J. (2002). *The analysis and interpretation of multivariate data for social sciences*. Boca Raton FL: Chapman & Hall/CRC.

Boyes, E., Stanisstreet, M., & Papantoniou, V. S. (1999). The ideas of Greek high school students about the ozone layer. *Science Education, 83*(6), 724–737.

Clark, J. H. (1999). Green chemistry: Challenges and opportunities. *Green Chemistry, 1*, 1–8.

Connell, S., Fien, J., Lee, J., Sykes, H., & Yencken, D. (1999). If it doesn't directly affect you, you don't think about it: A qualitative study of young people's environmental attitudes in two Australian cities. *Environmental Education Research, 5*(1), 95–113.

Eagles, P., & Demare, R. (1999). Factors influencing children's environmental attitudes. *The Journal of Environmental Education, 30*(4), 33–37.

Ehrlich, P. R. (2011). A personal view: Environmental education-its content and delivery. *Journal of Environmental Studies and Science, 1*, 6–13.

Gallezot, P. (2007). Process options for converting renewable feedstocks to bioproducts. *Green Chemistry, 9*, 295–302.

Gambro, J., & Switzky, H. (1999). Variables associated with American high school student's knowledge of environmental issues related to energy and pollution. *The Journal of Environmental Education, 30*(2), 15–22.

Hampel, B., Holdsworth, R., & Boldero, J. (1996). The impact of parental work experience and education on environmental knowledge, concern and behaviour among adolescents. *Environmental Education Research, 2*(3), 287–300.

Horizon 2020 Initiative. (2011). Measuring our water and carbon footprint: 20-21 June 2011, Athens, Greece, http://h2020.net/en/pollution-reduction-investments/the-project-mehsip-ppif.html. Accessed 15 February 2012.

Jensen, B. B. (2002). Knowledge, action and pro-environmental behaviour. *Environmental Education Research, 8*(3), 325–334.

Kirchhoff, M. (2011). International year of chemistry: An educational opportunity. *Journal of Chemical Education, 88*(1), 1–2.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239–260.

Kuhlemeier, H., van den Bergh, H., & Lagerweij, N. (1999). Environmental knowledge, attitudes and behaviour in Dutch secondary education. *The Journal of Environmental Education, 30*(2), 4–14.

Leimer, W. (2004). Focus on education in Green Chemistry. *Green Chemistry, 6*, 351.

Liarakou, G., Athanassiadis, I., & Gavrilakis, C. (2011). What Greek secondary school students believe about climate change? *International Journal of Environmental & Science Education, 6*, 79–98.

Lin, C., & Hu, R. (2003). Students understanding of energy flow and matter cycling in the context of the food chain, photosynthesis and respiration. *International Journal of Science Education, 25*(12), 1529–1544.

Loughland, T., Reid, A., Walker, K., & Petocz, P. (2003). Factors influencing young people's conceptions of environment. *Environmental Education Research, 9*(1), 3–19.

Meneses, D. G., & Palacio, A. B. (2005). Recycling behavior. *Environment and Behavior, 37*(6), 837–860.

Manzer, L. E. (2010). Recent developments in the conversion of biomass to renewable fuels and chemicals. *Topics in Catalysis, 53*, 1193–1196.

Metzger, J. O., & Eissen, M. (2004). Concepts on the contribution of chemistry to a sustainable development. Renewable raw materials. *Comptes Rendus Chimie, 7*, 569–581.

Naik, S. N., Goud V. V., Rout P. K., & Dalay, A. K. (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews, 14*, 578–597.

Newhouse, N. (1991). Implications of attitude and behaviour research for environmental conservation. *The Journal of Environmental Education, 22*, 26–32.

Papadopoulos, D. (2005) Development, implementation and evaluation of environmental educational programme on waste management, PhD thesis, National and Kapodistrian University of Athens, http://phdtheses.ekt.gr/eadd/handle/10442/15206 (in Greek). Accessed 15 February 2012.

Payne, P. (2005). Families, homes and environmental education. *Australian Journal of Environmental Education, 21*, 81–95.

Petrus, L., & Noordermeer, M. A. (2006). Biomass to biofuels, a chemical perspective. *Green Chemistry, 8*, 861–867.

Rye, J., Rubba, P., & Wiesenmayer, R. (1997). An Investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19*(5), 527–551.

Salta, K., & Tzougraki, C. (2004). Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education, 88*(4), 535–547.

Scoullos, M. (1998). Environment and Society: Education and Public Awareness for Sustainability. Proceedings of the Thessaloniki International Conference organised by UNESCO and the Government of Greece (8-12 Dec 1997).

Scoullos, M. (2007). Evolution and principles of the Education for Sustainable Development, Thalo, Vol I, "Education and Sustainability", July 2007 (In Greek).

Scoullos, M., & Malotidi, V. (2004). *Handbook on methods used in environmental education and education for sustainable development*. Athens: MIO-ECSDE.

Sharma, Y. C., Singh, B., & Korstad, J. (2011). A critical review on recent methods used for economically viable and eco-friendly development of microalgae as a potential feedstock for synthesis of biodiesel. *Green Chemistry, 13*, 2993–3006.

Sheldon, R. A. (2011). Utilisation of biomass for sustainable fuels and chemicals: Molecules, methods and metrics. *Catalysis Today, 167*, 3–13.

Sikdar, S. (2007). Sustainability perspective and chemistry-based technologies. *Industrial & Engineering Chemistry Research, 46*, 4727–4733.

Skamp, K., Boyes, E., & Stanisstreet, M. (2004). Students ideas about air quality. *Research in Science Education, 34*(3), 313–342.

Tikka, P., Kuitunen, M., & Tynys, S. (2000). Effects of educational background on students' attitudes, activity levels, and knowledge concerning the environment. *The Journal of Environmental Education, 31*(3), 12–19.

Trikaliti, A. (1995). Investigation of knowledge, social and psychological parameters related to Environmental Education. Ph.D. Thesis, National and Kapodistrian University of Athens (in Greek).

UNECE, (2005). High-level meeting of Environment and Education Ministries, Vilnius, 17–18 March 2005.

UNGA, (2002). Resolution 57/254, United Nations General Assembly, Dec 2002, adopting the UN Decade on ESD (2005-2014).

van Haveren, J., Scott, E. L., & Sanders, J. (2007). Bulk chemicals from biomass. *Biofuels Bioproducts and Biorefining, 2*, 41–57.

WCED. (1987). *Our common future. UN World Commission on Environment and Development*. Oxford: Oxford University Press.

Worsley, A., & Skrzypiec, G. (1998). Environmental attitudes of senior secondary school students in South Australia. *Global Environmental Change, 8*(3), 209–225.

Yilmaz, O., Boone, W. F., & Andersen, H. O. (2004). Views of elementary and middle school Turkish students toward environmental issues. *International Journal of Science Education, 26*(12), 1527–1546.

Zimmermann, L. K. (1996). Knowledge, Affect and Environment: 15 years of Research (1979–1993). *The Journal of Environmental Education, 27*(3), 41–44.