STUDENTS´ KNOWLEDGE ABOUT NANOTECHNOLOGY AND THE IMPORTANCE TO INTRODUCE NANOTECHNOLOGY INTO CHEMISTRY LESSONS

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ABSTRACT

The primary objective of this study was to find out what students already know about nanotechnology in order to design a context based module with a nanotechnology background. Therefore a questionnaire was distributed to 116 German students in grade 11. Questions referred to the first thought of the students´ mind when they hear the word nanotechnology, to the size of a nanometer, to if something can be seen at the nanometer scale with the unaided eye, to their self-assessment concerning nanotechnology and to the surface-to-volume ratio of nanoparticles. The findings of the students´ answers were informative and allowed us to design a module in the future that can lead students at school level to understanding nanotechnology. *[AJCE 4(4), July 2014]*

INTRODUCTION

During the recent years nanotechnology has emerged as the science of the material with dimensions: 1-100 nm. One nanometre is 1/80 000 of the diameter of a human hair. Materials in nano-size display unusual physical and chemical properties caused by many factors including the increase in its specific surface area [1, 2]. Nanotechnology has helped in improving the quality of ceramics [3], metals [4], polymers [5] and biomaterials which are responsible for the emergence of advanced technologies which will have an enormous impact in our everyday life. Future advances may alter our approaches to manufacturing, electronics, IT and communications technology.

Some of the commercial applications of nanomaterials are: sunscreens which make use of nano-size zinc oxide. It absorbs or reflects harmful UV rays of solar radiation [6]; self-cleaning windows which make use of nanomaterial of unique chemical properties which break down the dirt which can be washed away by rain and stain repellent fibres [7] which when coated over cotton can make the later water repellent.

Application potential of nanoparticles in catalysis ranges from fuel cell [8] to catalytic converters [9] and photocatalytic devices. Chemical catalysis benefits especially from nanoparticles, due to their extremely large surface to volume ratio. Catalysis is also important for fast production of chemicals. Because of the very high specific surface area of nanoparticles, the amount of platinum required in the catalytic converter has been significantly reduced. Therefore, platinum single nanoparticles are now being considered in the next generation of automotive catalytic converters [10].

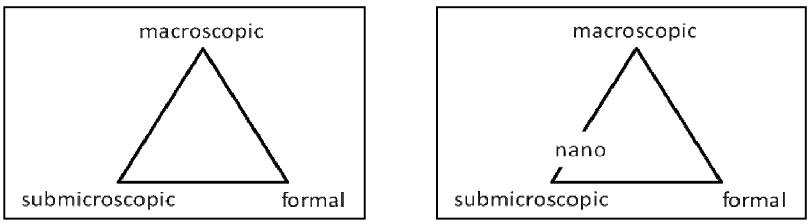
The future scopes of nanotechnology lie in the development of nanoelectronics [11] and computer technology, nanomaterials may allow the construction of smaller circuits which will not only reduce the size of electronic devices but will also make them run faster. Using nanotechnology, nanometer size solar cells [12] can be developed to provide much of the energy needed around the world and nanomaterials will increase the efficiency of fuel cells and batteries. Nanotechnology can also be used to tackle environmental problems. New 'green' processing based on nanotechnology will help in minimizing the generation of undesirable by-product effluents by curbing their emissions [13]. Recently developed biological nanosensors [14] will be used for fast and accurate diagnostics of diseases. In spite of the vast applications of nanomaterials in different fields it is also a matter of concern that nanoparticles may cause potential health and safety risks [15].

It is well known that nanoscale particles are more reactive than the same material in its bulk form, therefore, nanoparticles may be able to penetrate human cells. But till today, there has been carried out only a very limited research on the toxic effects of nanoparticles, if any, on the biological system and further research needs to be carried out by the scientific community in this direction.

Because the understanding of nanotechnology will be essential for the future [16], it would be beneficial and meaningful to introduce nanotechnology teaching into schools and universities. A lot of articles have been published recently on the subject of nanotechnology proposing ways for introduce it at university [17] and school level [18-21].

The area of nanoclusters, which consists of a special number of atoms, can be visualized by the ‘Chemical Triangle’ of Johnstone [22] (see Figure 1).

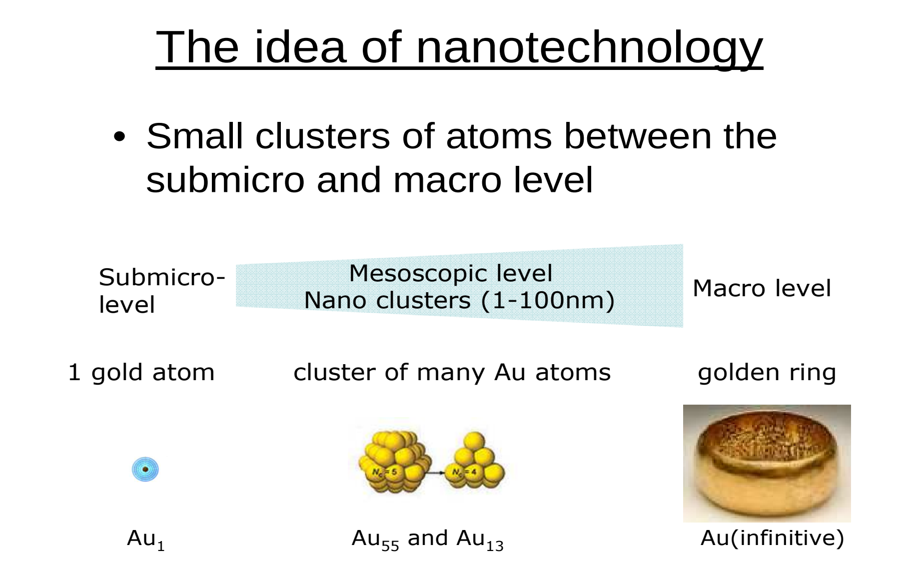
Figure 1. The chemical triangle of Johnstone, next to it a changed scheme



This triangle (Figure 1, left scheme) describes the three levels of reflection: the macroscopic level of substances and their properties, the submicroscopic level of chemical structures built out of atoms, ions or molecules, and the formal level of chemical symbols like formulae, equations and calculations. Between the submicroscopic and the macroscopic level, there is another area: the area of nano clusters or nano structures (Figure 1, right scheme).

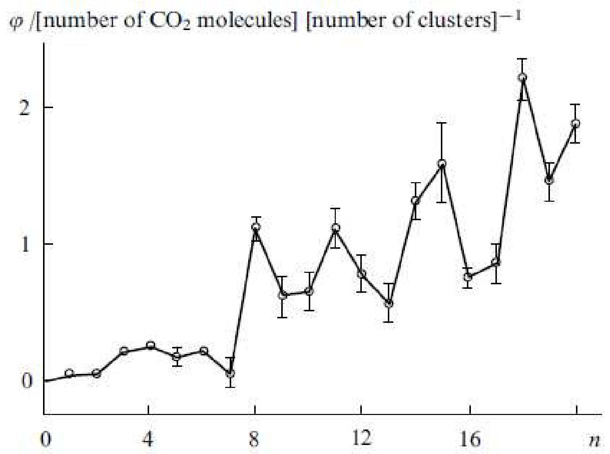
If we start with a single gold atom (Figure 2) we know that it is built up of a nucleus and a special number of electrons (submicro): the gold atom has no properties of a gold crystal. The well known properties of gold appear when we take an arrangement of about 10^{18} Au atoms: the visible crystal has the cubic face-centred crystal structure and the properties of gold (macro level). Between the crystal and the single atom exist special clusters of 13 Au atoms and 55 Au atoms [23]: Au_{13} und Au_{55}. They have other properties than the gold crystal, we can call this level of reflection the 'mesoscopic level' (see Figure 2).

Figure 2. Au-nanocluster between the submicro and the macroscopic level



It is impossible to explain these properties – they are mostly optical and magnetic phenomena which can be interpreted only by quantum mechanic effects. One of the properties of gold bulk material is the 'nobleness'. This property is getting lost in nano clusters if we investigate the catalytic activity of Au_n clusters as a function of the size of the Au_n cluster [24] in the reaction $2CO + O_2 \rightarrow 2CO_2$ (see Figure 3).

Figure 3. Yield of CO_2 molecules per cluster in the reaction 2 CO + O_2 --> 2 CO_2



As the sizes of nanoparticles decrease, the volume ratio of surface layers to the entire body, called the surface-to-volume ratio [25], increases up to 90% for a gold nanoparticle with a diameter of 1nm, for instance (see table 1). The atoms inside bulk crystals have optimum chemical bonds with all adjacent atoms. If the number of metal atoms (n) in the particle is less than 13, it has a close packing in which each atom represents a surface atom. For n = 513, two kinds of atoms exist, the inner and surface ones. The proportion of surface atoms in a cluster depends on the total number of atoms (see table 1) [26].

Table 1. Total Number of Atoms in a Cluster in Relation to the Surface Atoms

Number of atoms in a cluster	13	55	147	349	561
Proportion of surface atoms (%)	92	76	63	52	45

The trend in catalysis with nanoparticles is enormously increasing in the last years and a lot of scientific articles have been published to understand what happens with the chemical structure of catalytic materials in the nanoscale. The Nobel Prize in Chemistry 2007 was awarded to Gerhard Ertl for his studies of chemical processes on solid surfaces [27].

As nanotechnology is a very complex field it is difficult to introduce it into the school curriculum. But we can take a common topic – i.e. the catalytic converter - of the chemistry curriculum and may connect that topic with examples of nanochemistry as nanoparticles are included in many products we use daily in our lives.

Before doing so it is necessary to find out what students already know about nanotechnology. Therefore a questionnaire was designed and distributed to grade 11 students. The sample consisted of 116 students (70 young men and 46 young women) from 3 different schools in Muenster, Germany.

METHODOLOGY

The present investigation was carried out in Germany on grade 11 students at the beginning of a school year. The sample consisted of 116 students (70 young men and 46 young women aged 16 to 17 years) from 3 different schools in Muenster, Germany. The questionnaire consisted of 10 questions where students were asked about their knowledge concerning nanoparticles, the size of a nanometer, about nanotechnology products and their self-assessment. The questions asked are presented below.

Question 1 refers to what first comes up in the students´ mind when they hear or read the word nanotechnology. The answers given were divided into 5 categories. Question 2 seeks to find answers whether something in the nanometer scale can be seen with the unaided eye, a justification of the answer given was also required. As this question was not to be answered with a *yes* or *no*, categories were implemented according to the answers given by the students. Question 3 is about the analogy. Here, students are asked to give an answer to the presumption that if planet earth had a diameter of just one meter, what would have the diameter of a nanometer. They were asked to choose one out of 4 selections that were given: (a) the sun, (b) a basketball, (c) a tennis ball, or (d) a hazelnut. The latter one is the correct answer. In question 4 the students should select the products they think that are 'nanotechnology' products. The products they could choose were: tomato ketchup (product 1), the dirt repellent tablecloth (product 2), the homogenized milk (product 3), the sun blocker (product 4), the car paint (product 5), the toothpaste (product 6), a chocolate bar (product 7), and tinted car windows (product 8). The only product that does not belong to modified 'nanotechnology' products is the homogenized milk (product 3). By question 5 we wanted to know from the students in which science branch nanotechnology has its applications. They were able to select (a) chemistry, (b) physics, (c) medicine, (d) IT-branch, (e) biology, and (f) geology. All choices are correct. In question 6 students should estimate the nanometer scale and should select only the objects with a range of 1-100 nm, not less or more. The correct answer is the width of the DNA with a range of about 2.5 nanometers. Further possible answers that should not be selected were: an atom, a fly, a dust grain, and a flea. By question 7 we asked the students to assess their knowledge in the field of nanotechnology with a five-point Likert item: (a) absolutely no knowledge, (b) almost no knowledge, (c) little knowledge, (d) enough knowledge, and (e) very good knowledge. With question 8 students should state their opinion, if it was good/bad to be taught nanochemistry as a topic at school level. Also they were asked to justify their answer. Question 9 was related to the surface-to-volume ratio. The students were asked about what is the effect by milling crystal sugar into icing sugar, the change of taste or the change of surface area? Only the surface area delivers the correct answer. Question 10 should provide information about what is changing if a substance is powdered into a lot of small pieces. They were given four choices: the size, the chemical formula, the melting point and the state of matter. The correct answers are the size and the melting point.

The questionnaire should give a global information about students´ knowledge with regards to nanotechnology, about their imaginations, about their self-assessment and about what they think nanotechnology is. Also by the answers given we were able to realize if nanotechnology is important for them.

RESULTS AND DISCUSSION

Question 1 asked about what was the first thought that comes up in the students´ mind by hearing the word nanotechnology. In Table 2 we see that almost a quarter mentioned computer chips, electronic devices, and products that have been modified through nanotechnology like clothing and food (category 1). Twenty percent of the students stated that the first thought that comes up in their minds is something tiny, something very small (category 2), 17% mentioned a new technology, a 'small technology' (category 3). Category four is built by 14% of the students´ answers, they think of small robots that are used in medicine to diagnose and help the cure. In the fifth category 12% of the students connect the word nanotechnology with something coming from science but they mention having no concrete idea, whereas 13% of the students stated to have never heard of nanotechnology.

Table 2. Frequency of answers given to what first comes up in the students´ mind

category 1	category 2	category 3	category 4	category 5	no idea	total
28 (24%)	23 (20%)	20 (17%)	16 (14%)	14 (12%)	15 (13%)	116 (100%)

Question 2 was about being able to see something that is in the size of a nanometer with the unaided eye. We can see in Table 3 that almost three quarter of the students (74%) have an idea about the size. As an explanation of the students saying *no*, said that objects are too small to be seen with the unaided eye. Only 5% mentioned that objects in the nanometer scale can be seen with the unaided eye. The reason for being able to see something in the nanometer scale is 'yes, as we work with these materials'. Eleven percent of the students tend to say *no* but they are not sure and 10% of the students stated that they did not know whether something can be seen with the unaided eye.

Table 3. Can nanometer scaled objects can be seen with the unaided eye

No	I do not think so	No idea	Yes	Total
86 (74%)	13 (11%)	11 (10%)	6 (5%)	116 (100%)

Question 3 was about the analogy. Here, 62% of the students selected the correct answer which is the hazelnut, 26% decided the tennis ball and 8% went for the basketball. The rest chose the sun, which cannot be taken into consideration.

Table 4 shows the correct answers to the fourth question about 'nanotechnology' products:

Table 4. Frequency of correct answers according to nanotechnology products

product 1	product 2	product 3	product 4	product 5	product 6	product 7	product 8
15 (13%)	91 (78%)	81 (70%)	55 (47%)	83 (71%)	34 (29%)	6 (5%)	81 (70%)

Nearly 80% have heard about the lotus-effect that is used in clothing, so they selected the dirt repellent tablecloth (product 2). Seventy percent of the students do not think that homogenized milk (product 3) is a nanotechnology product and they did not select it, which is correct. Also 70% of the students chose the tinted car windows (product 8). In third position the sun blocker (product 4) is put by 47% of the students and on fourth position the toothpaste (product 6) is put by almost 30% of the students. Only one student selected all correct answers. 15% of the students answered correctly products 2, 3, 5 and 8. About 8% gave correct answers concerning products 2, 3, 4, 5 and 8.

According to the results in table 5 we can say that 92% of the students know that chemistry is involved in producing nanomaterials, probably for medical purposes, for computer chips, for ipod nano etc., as they already mentioned in question 1. In the second rank we find biology with 75% of correct answers, followed by physics with 71% correct answers. Only 52% of the students would classify nanotechnology into the IT-branch.

Table 5. Science branch where nanotechnology has its applications

Chemistry	Physics	Medicine	IT-branch	Biology	Geology
107 (92%)	82 (71%)	105 (90%)	60 (52%)	87 (75%)	23 (20%)

In question 6 a quarter of the students selected just the DNA width and so the question was answered correctly only by 21.6%. Just the atom was selected by 17 students (14.6%), 26 students (22.4%) chose the width of the DNA and the atom as well. Others chose only the dust grain, probably thinking of nanoparticle dust grains. The DNA width, the atom and the dust grain were selected by 16 students (nearly 14%).

Question 7 was about the students´ self-assessment. We wanted to know, what they think they know about nanotechnology.

Table 6. Self-assessment of the students´ knowledge about nanotechnology

Absolutely no	Almost no	little	enough	very good
50 (43%)	42 (36%)	23 (20%)	1 (1%)	0 (0%)

The first rank with 43% consists of the answer of having absolutely no knowledge about nanotechnology, second rank consists of 36% of the students who say that they have almost no knowledge of nanotechnology and only 20% of the asked students stated the opinion that having little knowledge of nanotechnology.

In table 7 we can see how students find the idea to be taught about nanotechnology at school and if it is interesting for them. They were asked to give a reason for their answers to question 8.

Table 7. Students´ opinions concerning nanotechnology in chemistry lessons

good	bad	neutral	I do not know	No answer
80 (69%)	7 (6%)	9 (8%)	15 (13%)	5 (4%)

Almost 70% would like to learn more about nanotechnology. Only 32% of the students stated a reason. They say that nanotechnology is interesting as our lives are affected by nanotechnology and it is important to have a good general education. Furthermore, they realize by filling this questionnaire that they have no idea about nanotechnology, as they stated. In 22% of the students´ opinion nanotechnology is important, it is modern and pioneering and leads to a better general education, 13% of the students could give no answer as they do not know what nanotechnology is like and 4% did not give any answer. Six percent of the students think it would be bad to introduce nanotechnology into school lessons as they would have to learn more whereas 8% are neither interested nor averse.

With regards to the surface-to-volume ratio in question 9 some of the students selected both choices (the taste changes and the surface area changes); these are not taken into consideration for the results as correct answers. This question was answered correctly by 97 students which make up a percentage of 84%.

In question 10 less than a quarter (22.4%) solved this question correctly. Fourty-four percent of the students had the opinion that nothing changes apart from the size and only 4% of the students indicated the melting point as the only change that occurs by powdering a substance into small pieces. About 16% of the students indicated a change in the state of matter in combination with other choices.

The purpose of this study was to find out what grade 11 students already know about nanotechnology and about the phenoma that are strongly connected to it. As the results show, students form their own view about nanotechnology even if they had not been taught about it.

They are used to new technologies, they all know what an ipod nano is and they hear about new achievements in medicine accomplished by nanoparticles. On the other hand most of them cannot classify the nanometer scale when they are asked to give an answer about objects in the nanometer scale. As to the question about their interest in being taught in school about nanotechnology most of the students would be grateful as they think it is pioneering and very important for their general education. Looking back to questions 9 and 10 we can realize that on the one hand they know about the surface-to-volume ratio but on the other hand they cannot connect the properties that change with increasing the surface and having a constant volume.

The designed questionnaire was informative in giving a first idea of the students´ point of view. With regards to the self-assessment of the 16 to 17year old students one can see that the majority has no knowledge at all or nearly no knowledge of nanotechnology.

A first module has been designed to connect nanotechnology with the car catalyst converter working with nano platinum clusters. First results on the topic of the automotive catalytic converter – which is the first step to introduce nanochemistry into school lessons is published [28]. Furthermore more daily products should be taken into account to connect them with nanotechnology in order to give students a chance to have a context-based knowledge which is required by the German educational standards.

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