BEAUTYILITY OF CHEMISTRY VISUALIZATION: WHETHER USEFUL CAN BE AESTHETIC

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Abstract

The analysis of aesthetic potential of Chemistry visualization is carried out, taking in account philosophical, didactic, psychological and socio-cultural aspects. The issue is discussed in terms of the concurrent existence of two different subsystems referred both to Beauty and Utility which can be found in presentations of chemistry knowledge. To be aesthetic means the need to be accepted as attractive one, and thus Chemistry ought to change its paradigm to form new attitude to Chemistry knowledge. The concept can be regarded as for valuable acquisition (and thus very useful!) to learning process. To be useful means the need to be accepted as utile. The latter have been the main intention for the last centuries which turned the Chemistry into generator of the most unexpendable resources for industrial development. And it looks very attractive when people gained the highest plane of intelligence to admire the Beauty both natural and man-made objects. Finally both Beauty and Utility potentials derived from Chemistry visualization can be effectively elaborated within the integrated Philosophical Concept of Beautility. Theoretical study based on profound concepts from Science and Chemistry philosophy as well on few empiric researches carried out by author in the field of Chemistry Didactics.
Key words: *beutility, chemistry, aesthetics, visualization, utility.*

"...as neere is Fancie to Beautie, as the pricke to the Rose,
as the stalke to the rynde, as the earth to the roote."
John Lyly, in his *Euphues and his England, 1588*

Introduction

What is Chemistry? Referred either to Craft, Art, Science or Philosophy? Why we need Chemistry? Only because we need products resulted from Chemistry activity? Or we could find from this activity something more: aesthetic and spiritual? What is beauty? And whether chemistry objects and their visualized forms can be regarded as beautiful, aesthetic? In fact, we need not be able to give an answer to these questions in order to vote. We could even imagine none of the voters being able to answer any of the questions in explicit terms. And yet, a few men might correctly regard those implicit definitions of what 'utility', 'beauty', and 'chemistry' means in context of philosophical consideration. The result thus reflects the underlying knowledge and the unquestioned feelings of the majority, as they have previously been trained to respond to such unusual questions. But when discussing the role and the place of Che-

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mistry within cultural context it helps us, Chemists and Chemistry educators, to facilitate newcomers acculturating the issue easily.

Thus we are facing two approaches, two paradigms. Whether we need Chemistry only because of its usefulness, or we can find in this activity the Extra-meaning, inducing the new understanding of beauty and thus aesthetic and spiritual.

Dominated by a pragmatic thoughtways, the author of the article have chosen as recently as a quarter of a century ago Chemistry as a very practical and applicative field of knowledge. After graduation from the University and Ph.D program a young Chemistry newcomer moved to a determinate variation from "Pure Science" to "Applied Didactics" and started his professional career as Uni Professor. And finally he perceived the importance to find "beautiful meaning in beautiful things" (shortened rephrasing from O. Wilde). And still pursuing both scientific and academic activity regarding their practical utility the author started his way to reveal the aesthetic potential of the objects he dealt with, namely the *Chemistry objects*. And it was easy enough to find the beauty of real objects. Fine design of chemical glassware, a specific aesthetics of the chemistry laboratory, which was functional and enigmatic at the very same time, and finally (trust *Organic chemist* to say that!) substances with their smell, colours and tendency to behave in way scientist can not predict… The attraction of chemistry in that context was perfectly expressed by Robert Woodward (Nobel Prize, 1965), uncrowned king of organic chemistry design, who was in part the challenge of performing syntheses that no one else could carry out (still very pragmatic context, but it was certainly the sensual aspects of the subject, too). "It is the *sensuous* elements which play so large a role in my attraction to chemistry. I love crystals, the beauty of their form – and their formation; liquids, dormant, distilling, ***sloshing***; swirling, the fumes; the odors – good and bad; the rainbow of colors; the gleaming vessels of very size, shape, and purpose. Much as I might think about chemistry, it would not exist for me without these physical, visual, tangible, sensuous things." (Woodward, 1984, p. 137). The problem arose when students and professor giving them chemistry knowledge encountered 'unreal objects", which represented "visualized Chemistry meaning". And the author tried to discern the attractiveness of micro-objects in great distance which can be overcome through visualisation techniques. You find the author romantic to excess? Still no more than it's required from the educator. The main reason was to reveal the beauty which might help him to motivate student to teach chemistry and thus make teaching more effective. Just we can say about very pragmatic and utile reason. Still the author followed simply the Nobel Prize winner Robert Mulliken who confessed that he "….loved molecules in general, and some molecules in particular" (Mulliken, 1968, p. 19).

We revert to the point we started from: just beautiful and useful and it's referred to Chemistry. And Visualization is the way we facilitate the understanding of both entities within the subject.

Discussion

The beginnings: few attempts to understand the terms and find the common denominator of what I try to present as "aesthetic usefulness".

Utility is a quality of being useful and can be regarded as a measure of the happiness or satisfaction gained from a good or service. „The quality or condition of being useful; usefulness. " (Dictionary of the English Language, 2000) The term originates from Old French *utelite*, from Latin *ūtilitās* – usefulness, from *ūtī* – to use.

Beauty is „the quality that gives pleasure to the mind or senses and is associated with such properties as harmony of form or colour, excellence of artistry, truthfulness, and originality (Dictionary of the English Language, 2000). It originates from Middle English *beaute*, from Old French *biaute*, from Vulgar Latin *bellitās*, from Latin bellus, *pretty*; thoght from common Indo-European roots.

Beauty is a characteristic of a person, animal, place, object, or idea that provides a perceptual experience of pleasure, meaning, or satisfaction. Beauty is studied as part of aesthetics, sociology, social psychology, and culture. As a cultural creation, beauty has been extremely commercialized. An "ideal beauty" is an entity which is admired, or possesses features widely attributed to beauty in a particular cul-

ture, for perfection. Beauty has different meanings in different cultures and eras--but everybody has some idea of beauty (even the Hell's Angels!!!). Although humans can not agree on specific examples, we do all share a general formula for beauty: It has a very pleasing physical sensual element combined with mental enlightenment. "Aaaahs" and "Ah-has." It is the combination. There is an intellectual component to a beautiful person and an emotional component to a beautiful mathematical proof. The experience of beauty is the result of the convergence of body, mind, and soul. Form and function melt together. Art and science dance. Compared to survival, beauty may not be a critical necessity like air, but beauty is certainly not a luxury either. Beauty drives evolution. In **Sleeping Beauty,** the evil queen had to ask her mirror what was beautiful (obviously she was not a designer). "Mirror, mirror on the wall, who's the fairest of them all?" (Quality is reflected in the visual image). The way things look is important. Is it only skin deep? You can judge a book by looking at the cover!"

Economics grab all the headlines but beauty is just as important, and even has serious financial ramifications. Beauty does serve a function. Beauty is more than skin deep. Beauty is powerful. Utility is beautiful and beauty has utility. Let's call it **'Beautility'** for short. Thus beautility is a definition for objects that is both beautiful and useful, generally objects of special design (industrial, handmade, and finally in our case synthetic origin) which are meant to have utility while having a pleasing aesthetic. Like water and health care, Beautility is an essential civic utility that sustains our life form.

Scientific visualization is an interdisciplinary branch of science "primarily concerned with the visualization of 3-D+ phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component" (Friendly, M. & Denis, D. J., 2001). It consists of many subcategories and a plenty of applications in different spheres including those in the field of chemistry.

Amplification: the investigation of model-visualization technique to represent Chemistry knowledge both useful and beautiful.

Based on the experiment (the initial stage was almost completely empirical) the chemistry gained the new paradigm which rather formal by nature and fundamental in methodological meaning. Still the tool for inter-conversion between the empiric and theoretical moieties seems to be the core point of the consideration. Earlier we postulated (Lakhvich & Shantar 2006, Lakhvich, 2007) the visualization is to be the core element for the modern Educational model and Paradigm for Chemistry. This category is sometimes associated with the problem of modelling, which is one of the most important in modern chemistry. Two issues of International Journal for Philosophy of Chemistry, devoting to the problem, confirm dramatically its relevance. Still the discussion in many aspects manifested the initial stage of the recognition, models mostly being discussed in terms of molecular recognition and computational modelling. We consider the category of visualization is more comprehensive and can be discussed in various aspects, some of them are all-pervading philosophy principle (Harnad, 1987; Ernest, 1990)), psychological tool for cognition and finally the model having for chemistry its own complex structure (See figure 1).

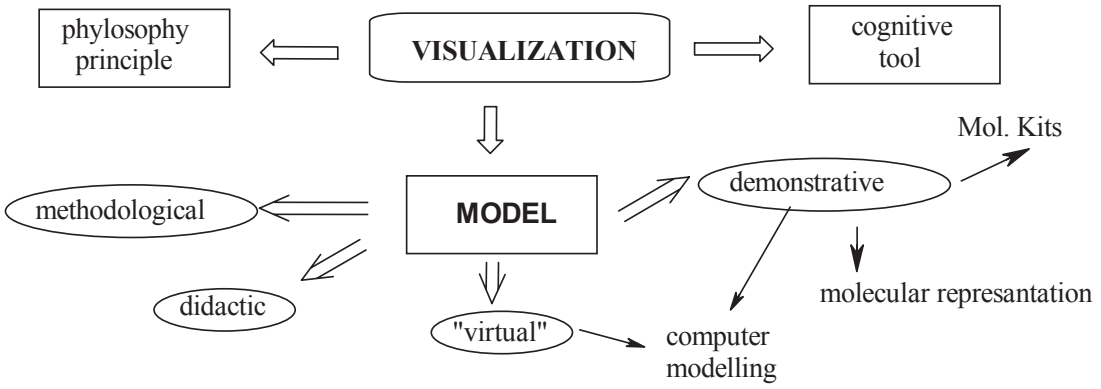

Figure 1. The structure of Visualization category.

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The model category is of priori interest for Educational Chemistry, the psychological aspect being of our special interest for last decade (see references below on our experimental studies) while the development of more effective didactic schemes for teaching both in high and higher school.

Models are used in all scientific disciplines. It's worthy to note they are appropriate not only for theoretical considerations but useful in the framework of more practically oriented fields of chemistry. The typology of models has been developed regarding the hierarchy of the latter in dependence of their relative similarity (Trindle, 1984; Tomasi, 1988).

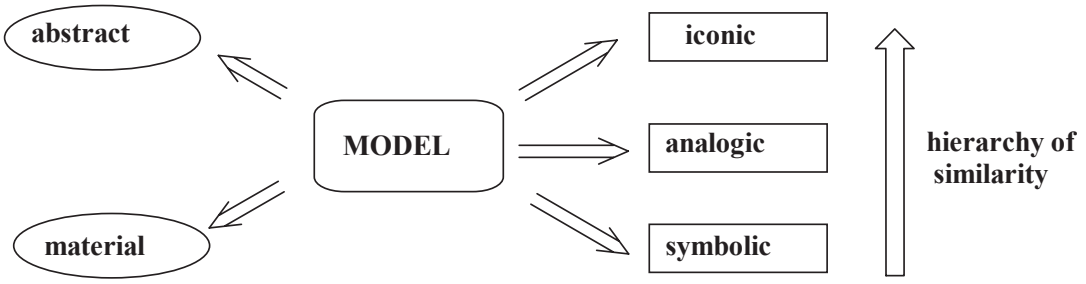

Figure 2. Hierarchy of models.

Still it has been found (Tomasi, 1999) for theoretical investigation in chemistry the models can be classified in other way, the components of this subsystem are hierarchally dependant and the most comprehensive definition refers to so called interpretative model. The latter collects all the aspects of study which are used for interpretation of the application of the mathematical model to the material model, according to the limits and condition the physical model superimposes. The interpretative model is absolutely appropriate for speculation of different chemical concepts; the adequacy of such a model ought to be judged with the aid of some criteria (See figure 3).

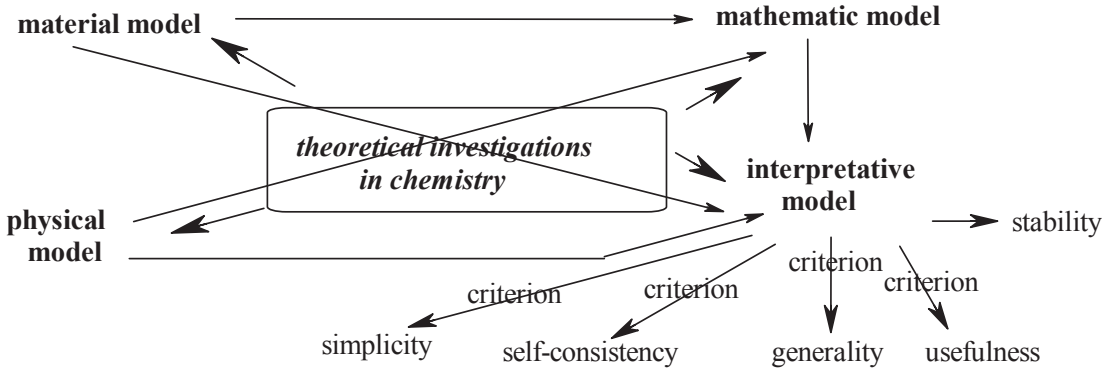

Figure 2. Hierarchal dependence of models.

There have been postulated (Lakhvich, 2005) a few additional criteria to judge models in a didactic framework. Models for the academic disciplines need to be adequate, effective, contemporary, exciting, and finally appropriate for successive usage (taking in account the need for continuity of education). The similarity between real objects and models can almost be neglected in this context. To create an effective didactic model, we need to accept the influence of many features and conditions, which include both the nature of real objects and didactical (for the academic disciplines) aspects.

Just postulating the model/visualisation is to be exciting we strengthen the idea about aesthetic potential of chemistry knowledge. And playing with definitions we can find a symmetry which both entities form within the area of their interaction.

Chemistry is cornerstone of a scientific paradigm: it operates the body of exact sciences, explores the nature and concerning many humanitarian and social issues. Based on the experiment (the initial

stage was almost completely empirical) the chemistry gained the new paradigm which rather formal by nature and fundamental in methodological meaning. "Chemistry, the art, craft, business, and now science of substances and their transformations, is today paralleled at every step by hard-won microscopic knowledge of molecules and their reactions" (Hoffmann, 2003). Chemistry is also human labour, and/or matter of their activity. For those it gives both feeling of inspiration and sense of achievement as the feeling of spiritual gratification. Their products (both mental and tangible) originate perception of other people and thus granting the form and essence of what Chemistry induced.

Aesthetics is commonly known as the study of sensory or sensory-emotional values, sometimes called judgments of sentiment and taste. It may be defined narrowly as the theory of beauty, or more broadly as that together with the philosophy and "critical reflection on art, culture and nature" (Encyclopedia of Aesthetics, 2003, p. 24). Aesthetics studies new ways of seeing and of perceiving the world. *Thus, Aesthetics is cornerstone of a spiritual paradigm: it operates the body of fine arts and Philosophy, reflects the nature and concerning many humanitarian and social issues.*

The italicized phrases and references to Chemistry and Aesthetics reflect the symmetry and interpenetration of both entities: scientific (empiric, objective and utilized) and sensual (spiritual, subjective and ephemeral), forming the symmetry of the World, and the latter looks very aesthetic.

Onlooking: how the others see aesthetics and Chemistry aesthetics

The philosopher Denis Dutton identified seven universal signatures in human aesthetics which have been summarized in (Pinker, 2002):

- Expertise or virtuosity. Technical artistic skills are cultivated, recognized, and admired.
- Nonutilitarian pleasure. People enjoy art for art's sake, and don't demand that it keep them warm or put food on the table.
- Style. Artistic objects and performances satisfy rules of composition that place them in a recognizable style.
- Criticism. People make a point of judging, appreciating, and interpreting works of art.
- Imitation. With a few important exceptions like music and abstract painting, works of art simulate experiences of the world.
- Special focus. Art is set aside from ordinary life and made a dramatic focus of experience.
- Imagination. Artists and their audiences entertain hypothetical worlds in the theatre of the imagination.

It might be objected, however, that there are rather too many exceptions to Dutton's categories. Some of them were found in the field of Chemistry, and especially when we regard its utilitarian potential. Still providing utility of products created the Chemistry reveals its own aesthetic potential, derived both from utilitarian and nonutilitariam paradigms. The issue has been discussed in different contexts. Thus *J. Shummer* used a wide variety of aesthetic theories suitable for an investigation of three basic types of chemical products – materials, molecules, and molecular models (Shummer, 2003). Another aspect of *Shummer & Spector* research revealed the importance of visual stereotypes of chemistry as they occur in portraits of chemists, depictions of chemical plants, and images of chemical glassware and apparatus (Shummer & Spector, 2007). They concluded that chemists, along with commercial artists, have unknowingly created a visual image of chemistry that frequently conveys negative historical associations, ranging from imposture to kitsch. Other elements of this image, however, aestheticize chemistry in a positive manner by referring to classical ideals of beauty and borrowing from revered motifs of modern art. R. Root-Bernstein reflected his own experience to show the importance of sensual, aesthetic, and even artistic considerations as motivation for general interest in chemistry and the development of specific research problems (Root-Bernstein, 2003). *Ph. Ball* in nice historic overview created his own list of "ten beautiful experiments in chemistry" (Ball, *2005)*. In fact he has been seriously searching for the role of aesthetics in chemistry before, though not in the design of experiments. Few authors explored unusual issues concerning Interrelation between Chemistry and Aesthetics, such as aesthetic nature of the computationally rendered representation of HIV protease, an analysis of the aesthetic function and

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properties of molecules is undertaken, with particular emphasis on the properties of tension, elegance, and sublimity (Spector, 2003).The other point explored the importance of Chemistry presentation in fiction (Ball, 2006), fiction films and museums (Morris, 2006).

Our contribution: what we have done to explore the aesthetic and utility potential of Chemistry visualization in Education practice. "Useful results" derived from "beautiful meanings".

During the last 5 years we explored the problem of Chemistry modelling and visualization. Models for the academic disciplines need to be adequate, effective, contemporary, exciting, and finally appropriate for successive use. We postulated a few additional criteria to judge models in a didactic framework (Lakhvich, 2005). During evaluation of these criteria we explored their aesthetic potential in context of presentation and visualization of chemistry objects, as well as enhancing students motivation to learn Chemistry, which is aesthetic not only because of material objects, but also in its "ephemeral" imaginary content. The similarity between real objects and models can almost be neglected in this context. To create an effective didactic model, we needed to accept the influence of many features and conditions, which include both the nature of real objects and didactical (for the academic disciplines) aspects. Within the framework of our previous studies we explored the effectiveness of different visualization and modeling techniques including the usage of Condensed Visualization Technology.

The empirical study showed the effectiveness of the didactic system proposed both for University and School students (Lakhvich, 2006; Lakhvich, Traunikava & Efimava 2007; Lakhvich & Traunikava, 2009). Within the experiments we judged the adequacy of Condensed Visualization Technology approach for structuring the course of Chemistry. That approach was indicated to be more effective tool (compare to traditional approaches) for teaching Chemistry in didactic, methodological, cognitive aspects. The methodology elaborated was shown to be useful for analogues studies. We suppose condensed scheme technological approach can be used for teaching chemistry both in high and University school. It's very effective and provides good results particularly useful for short-period learning.

The special attention of our study was centred on the problem of the acceptability of CVT approach in general (grade 8–10) and preuniversity (grade 11–12) school. On the basis of empiric data obtained (Lakhvich, Traunikava & Efimava 2007) we consider 8-10 grade school students are psychologically capable to perceive such level of formalization. The latter, to our mind, facilitates to the formation of so called Chemistry type of mentality and force the possible reactivity of hit site of the molecule on students' attention. The introduction of such approach represents the generalized model of graphic visualization as methodological and didactic tool for structuring the modern course of Chemistry.

Appealing results from pilot experiment justified the acceptability of visualization type presentation of chemistry information for primary school (Lakhvich, Lehankova & Traunikava, 2008; Lakhvich &Lehankova, 2009). Thus we obtained 6–7 year pupils is capable to resolve correctly problems in the field of Organic Chemistry, including tests on variety addition and substitution reactions (e.g. addition of methyl lithium to methylcyclohexanone) in the case we presented aesthetic and psychologically adopted technology. Grounded on the results of the experiment we postulated the need of propaedeutic introduction of the chemistry language semantic subunits in m primary school as the reflection of aesthetic potential of molecular representation. The main reason for such approach ought to be the realization of illustrative and imaginary thinking familiar to children of this age group. The other reason was to facilitate the learning of systematic course of Chemistry on the basis of the semantic system presented in propaedeutic introduction of molecular representation. Surely the approach required the adequate visualization techniques which included both excited samples (graphic and computer) and psychologically adaptive system of successive information presentation (CVT Technology).

The last contribution was made in the framework of the pilot project aimed to facilitate the process of teaching hearing impaired students (Lakhvich, Kostarava & Lehankova). The investigation was carried out within the period of 3 months and included different forms of visualization-based educational techniques. The latter included various models, animations, chemistry experiment, play-therapy and etc.

Animations assisted different topics of general course and the emphasis was made to form a visual-based acceptance of chemistry information, regarding the attractiveness and age-related accessibility of the models proposed. Thus the concept of valency was visualized in form of 4-handed (for Carbon), 3-handed (for Nitrogen), 2-handed (for Oxygen) and finally 1-handed (for Hydrogen and Halogens) mannikins. They were allowed to form chemical bonds and structure taking in account their valency/handy-capacity. Discussing topics from organic chemistry the isomerism of organic compounds was visualized in the same manner, in addition various animals were proposed as the imaginary models of chemical elements. The initial introduction of visualized social and/or domestic patterns followed by the interchange of the latter for geometrical figures grouped in proper manner and finally to structural formulae. The special attention was made to use of condensed visualization technology elaborated earlier and accessed for regular pre-university and university students.

The approach had been pursued in the framework of game-learning therapy. The latter included students cast, which played elements forming chemical bonds. The game enhanced the usage of additional sensors accessible for deaf students (visual, tactile and kinaesthetic). The positive motivation facilitated study process.

Preliminary investigations showed great motivation of HI students to carry out experiments in school laboratory. The latter obviously correlates with the fact that impairing hearing has little effect on the ability to work in the laboratory. Moreover circumstances are favourable for such students to realise their potential in science. We used the potential of the chemical experiments both in individual and collective forms. The latter was supplemented with graphic presentations, 3D-animations, molecular modelling and play therapy activity. We consider the schematic type of presentation when being aesthetic and adequate should facilitate the teaching process regarding the psychological aspects of "commix"-type of mentality familiar to recent generation "commix".

Finally we prepared the didactic materials (Lakhvich & Traunikava, 2009) based on the technology and our understanding of what is to be aesthetic to facilitate teaching process.

Few Ideas in Conclusion

Chemistry and Aesthetics can be regarded as cornerstones of two interfering paradigms: scientific and spiritual, taking the *racemic* whole when two *enantiomorphic* objects ajusting together. Aesthetic analysis of Chemistry meaning includes the cultural image of chemistry as well as chemistry's contribution to the image of the world and chemists behaviour to arrange-explore-produce their laboratories, instruments, materials, texts, research objects and, finally results, in accordance with aesthetic criteria. Visualization and modelling of chemical information, which are of major priority for chemists, who more than any other scientists communicate with each other through images and symbolic units, comprise a special issue for consideration.

Empiric results from our previous study confirmed the idea adequate and aesthetically designed visualization promote motivation to Chemistry teaching and facilitates the understanding/encoding of "encrypted Chemistry meaning". To be aesthetic means the need to be accepted as attractive, and thus Chemistry ought to change its paradigm to promote a new attitude to Chemistry knowledge. Usefulness means beautiful as beauty can be regarded the main spiritual motif for the development of the technology. And otherwise aesthetically designed products, including Chemistry objects and Chemists' activity seems to be useful and pragmatically aimed to satisfy the expectation of modern people "cultural and humanitarian-tendency" appetites of our time. And the best way to find the way from chemistry objects to sensual perception of a man is to visualize aesthetically encrypted Chemistry information.

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