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INTEGRATION OF MATERIALS SCIENCE IN THE EDUCATION OF HIGH SCHOOL TEACHERS IN AN ADVANCED COURSE PROGRAM

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Dedicated to Prof. Jung-Il Jin, Seoul, Republic of Korea, former President of IUPAC, on the occasion of his 70th birthday.

ABSTRACT

A concept for an advanced course in polymer materials science for students of Chemical Education is described in which creativity and curiosity for scientific problems are challenged. This ambitious concept that can be conducted with small groups and well-equipped laboratories can uncover otherwise hidden potentials of the students.

Keywords: *interactive lab course, Advanced Materials Science Education, interactive instruction manual, creativity, motivation, encouragement*

INTRODUCTION

In courses for students of Chemistry who want to become teachers it is frequently observed that the content of the classes is separated from the lab course and that the correlation of the lectures and the lab course is often poor. The students do not have much influence on the specific content of the course; they perform prescribed experiments generations of students have done before in the same way. In materials science, the students do not only deal with the general properties of materials and their determination, for example mechanical behaviour, thermal properties etc., an important issue is the correlation of structure, morphology and properties of the material. Understanding complex interactions and non-linear chains of cause and effect is an essential learning target where inflexible teaching concepts are not really satisfying. We can teach many facts in a course but essentially is what remains with the students as real knowledge. In the particular case of students who want to become teachers, there is a strong demand for showing them not so much a collection of separate techniques and properties but a broader perspective of how things cooperate [1, 2] Having experienced this in a specific field with a particular substance and with certain techniques they should be able to transfer this picture to other systems and other techniques without major problems.

This is a report of a project-focused approach with a range of flexibility left for the students' creativity that has been carried out at the Gerhard-Mercator University, Duisburg, Germany, in advanced courses for students of Materials Science Education.

During this specific course, the students were allowed some degree of interactive freedom to decide which experiments they think should be conducted and in which sequence. In Materials Science, in particular in the field of organic polymeric materials, one can start from the very basics, means from monomers that can be polymerized to different kinds of polymeric materials such as homo- and copolymeric bulk polymers, polymer blends or composites. The students can become creators of the materials they are working with, a very important experience with respect to the measurements they perform later with exactly these substances. They continue their experiments not with some kind of anonymous sample from the lab assistant but with their own material. This concept in some sense puts into practice Peter Mahaffy's tetrahedral view on chemical education.[3]

In international courses, means in courses where there are students from different countries, modern teaching instruments like electronically available manuscripts provide a chance incorporating and combining matter-of-fact information with language information in a very useful way which is not only comfortable for students from foreign countries. These options should also be considered in up-to-date teaching.[4-6]

RESULTS AND DISCUSSION

During recent years several courses in (polymer) Materials Science were conducted with the scope to show the students not only how materials behave but also why they behave as they do and in which way this can be controlled. So, the questions are, for example, why is this material strong (and what does it mean "strong") and another one "weak", why does this sample (of the same material) pass a test but another sample fails, how can we control the properties of a material and to which extend.

The basic idea is to give the students an idea of a material, literally a "feeling" for a material. Therefore, after some weeks of introductory class room teaching where the very basics of Polymer Chemistry are presented, the lab course starts with the synthesis of a particular polymer. This can be done applying different techniques or varying experimental conditions, see Figure. 1. A certain general direction is of course predetermined, say, let us study polystyrene or how to cover a metal surface with a polymer. The students are then asked to develop a strategy how to conduct the investigation. Provided there are not too many students in a course and that there is a good hardware background, the students can develop many different ways to discover their unknown territory actively.

The students work in groups of two to four. The feeling of putting into shape their own practical course wakes up hidden potentials of creativity and encourages using their brain and following their own ideas, eventually forming a real research team. The tutor observes, guides with "slackened reins", helps and assists and only interferes when really necessary. Guidance has to be strict only in the beginning and it was observed that very soon a team forms from the accidentally assembled group, and an increasing degree of self-confidence is formed where even weak students find their strength and grow with their task and success. Because the individuals can play their part (one student is good at synthesis, the other good at physical

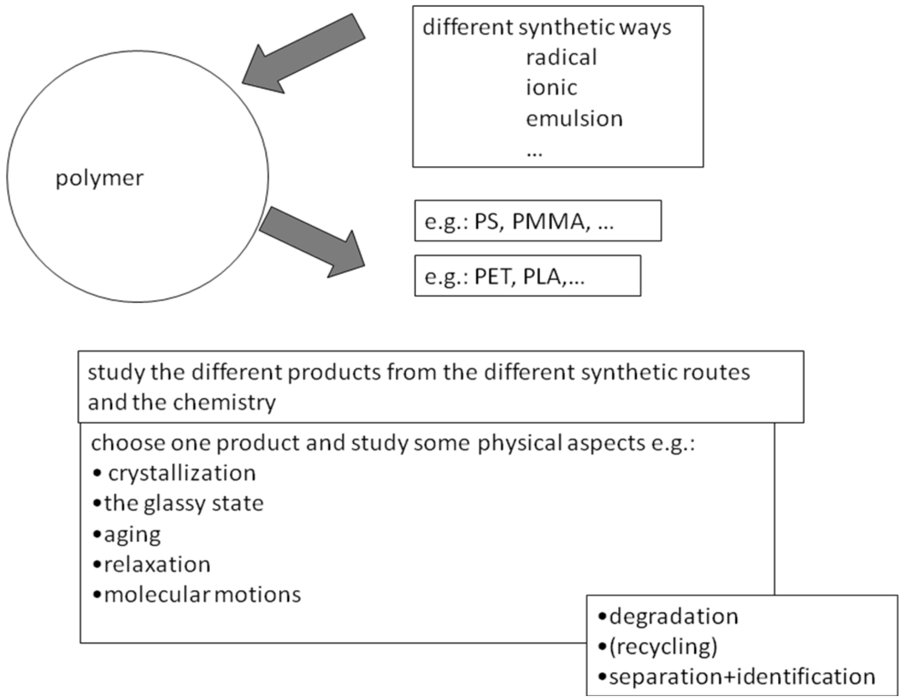

Figure 1. General scheme how a Materials Science project can be started from the synthesis of a polymer

measurements, another one good at data evaluation etc.) literally everyone finds her/his field of expertise, brings it in, finds her/his value in the team. This definitely increases the individual learning efficiency. The effect that weak students are only carried forward by better students decreases. The weak students rather improve their skills and understanding in such a team and gain confidence.

Another effect is that students look at a sample specimen that has to be characterized with much different eyes when they have prepared the sample themselves, when they have some degree of freedom to decide what to do with it. As an example could serve polystyrene as polymeric material: polystyrene is synthesized with different techniques. Different methods to characterize the product are chosen and compared. After the first results, say determination of the different molar mass averages, automatically the question arises what happens when experimental conditions are changed. At the same time handling the experimental data wakes up curiosity, this leads the students deeper into the matter and hence to a better understanding – literally "grasping"– of the physical meaning of the terms they are dealing with. Having the results from, say, chromatography, the question might arise: does this fit in with osmometry and viscosity,…, what if we change the conditions of the synthesis…

Now, what kind of a material do we have got? Is it brittle or elastic? What exactly does that mean? Calorimetric and dynamic mechanical analysis can help with hard physical data. Soon the students find out that they are dealing with solid state properties, terms like glass transition, etc., one could use microscopy for analysis of the fracture…Many branches of materials science open up once a material is produced, with careful guidance by the tutor a general strategy can be followed with a lot of input from the students.

Smart students can be allowed to follow unexpected effects they might identify such as the enthalpy relaxation that leads to physical aging processes and general relaxation phenomena. In the class and in seminars it is then possible to go deeper into the matter.

Another example is silicon chemistry that can lead into the fields of rheology of liquid polymeric products, rubber elasticity and even the effects of frequency-dependent deformation behaviour when "bouncing putty" is synthesized. There are many more examples which can be taken from what is present in daily life and deals with the general question: why does this material behave in this way, can I change the behaviour, how and to which extend. After all, this can lead to an understanding of how to think and approach a problem where a material has to be tailored, see Figures 2 and 3.

The students experience that they are not (passively) taught but they are actively learning, that they are the ones who go forward once their curiosity and enthusiasm woke up and they find out that their ideas are taken seriously. The effect is that the students are much more going for good and consistent results than "just for the grade points". They learn more because they just want to know, and exactly this is what they later as teachers at high schools and colleges have to forward to their pupils. To show them that the materials we are dealing with in daily life did not just fall out of the sky but were developed, can be created by careful and mindful observation followed by applying proper science and combining different disciplines of science and engineering. Basis of all is reveille curiosity and create self-confidence in the students

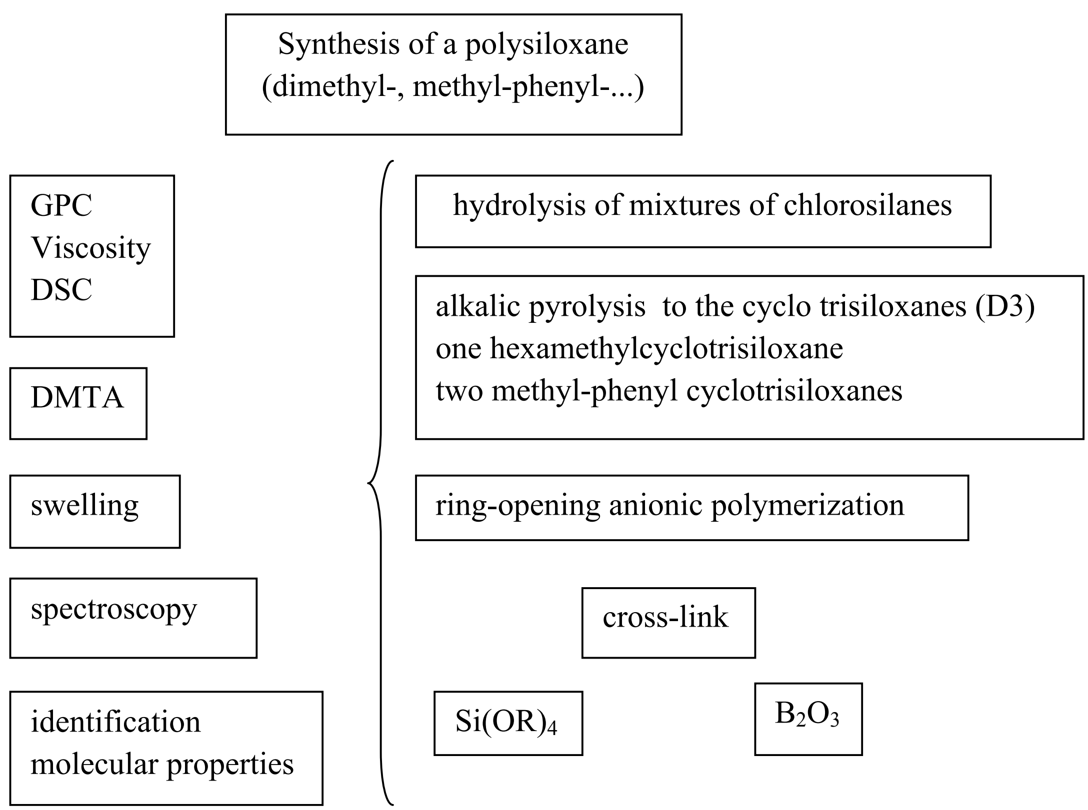

Figure 2. Example of an experimental project: from a synthesis to property evaluation.

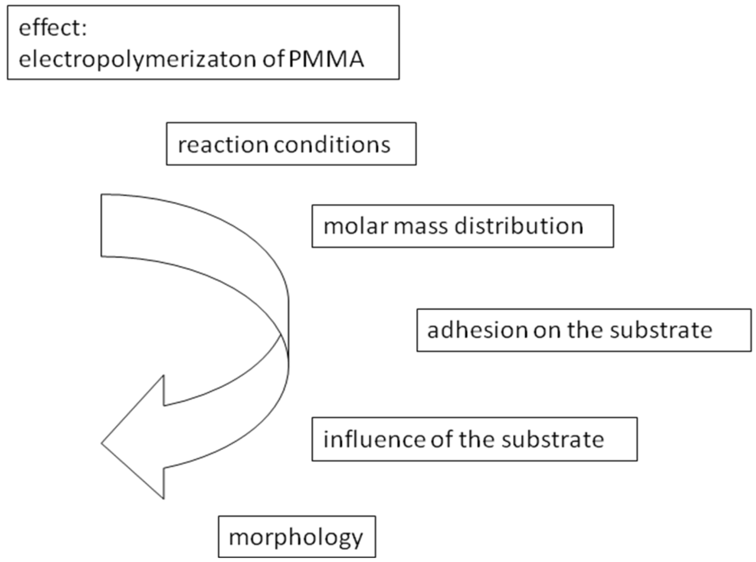

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Figure 3. Correlation between experimental parameters and different materials properties: electropolymerization on to a surface as an example

In groups of students of different mother tongue the learning effect can be significantly enhanced by the use of electronic teaching media that allow not only matter-of-fact information about the proper terms of the equipment used and links to general sources of information such as the IUPAC recommendations on terminology and nomenclature[7, 8] but that also provide terms in different languages on demand in the teaching material like in an on-line dictionary in a "click-and-translate-mode". For example, a liquid-liquid extractor is mentioned in the text. A link leads to a corresponding figure giving the names of the individual parts with further links to translations to different languages. This can be in particular of interest for languages using special characters such as Chinese, Hindi, Arabic or Korean. Same can be done with chemical terms that can be linked to the online version of the IUPAC Gold Book (Compendium of Chemical Terminology)[9] that contains more than 7,000 entries providing the correct definition.

Further reading for integrating of the tremendously growing fields of nano-technology and biomedical materials science can be found in Skoulidis et al.[10] and Shieh et al.[11] New trends and developments in Materials Science have to be incorporated in a curriculum as early as possible to make the teaching up-to-date, another way to generate the students interest in the problems of Materials Science. Giving a solid scientific ‘stem’ with the historic development of materials science together with ‘young shoots’, i.e. the most recent developments, on the ‘old stem’ and realtime active involvement of the students makes the curriculum most attractive. Sometimes boosting areas of Materials Science do not exactly come with advertizing, popular adjectives like ‘nano’, ‘high performance’ or ‘sustainable’ but have an amazingly close ‘hand on problems’ relation to our daily life, as for example shown by Brostow et al.[12, 13]

It is a big difference to explain the principles of Materials Science to university students, to college undergraduates or to high-and middle school students.[14] This also has to be considered in the educational curricula.

CONCLUSIONS

Controlled self-developing lab-courses in Materials Science can provide a more profound learning effect in contrast to a rigid, inflexible curriculum. This has to go along with a correspondingly flexible class respectively seminars that go deeper into special topics of a problem as it becomes necessary. Good results can be obtained with a small number of students allowing them to identify problems or interesting questions worth to investigate by themselves with only a limited guidance by a tutor. Starting with the synthesis of a polymeric material following lines of interest identified by the students themselves guided only by a minimum of "tutorial reins" result in a higher engagement and more enthusiasm, leading to a kind of a self-propelled learning that strengthens the self-confidence of the students. This type of a practical education is often more effective compared with pre-programmed learning.

The advantage of this concept leads to a deeper interest of the students in their subject, a faster process of learning, activation of the student's potential of imagination, curiosity, brain storming and teamwork. They actively start creating ideas and do not so much follow described routines, they feel challenged.
Disadvantages certainly are that such a concept only works with a small number of students, and skilled assistance is required with supervisors suited to non-routine courses where a high degree of flexibility is inevitable. Good research equipment should be made available and last not least good students are needed, students who are not going for a just a grade in the first place but who are interested in the subject they want to study because they do not want to be fed with facts but want to gain knowledge.

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REFERENCES

1. E. Garfield, 'New Tools for Navigating the Materials Science Literature', *J. Mater. Ed.* **16**, 327-362 (1994)
2. E. Werwa, 'Everything you've always wanted to know about what your students think they know but were afraid to ask', *J. Mater. Ed.* **22**, 18 (2000)
3. P. Mahaffy, 'Tetrahedral Chemistry Education: Shaping what is to come', *Chem. Int.*, **26**(6), 13 (2004)
4. S. Zekri, L.M. Clayton, A. Kumar, G. Okokbaa and L. Martin-Vega, 'Long term integration plan of nanotechnology and material science into fourth and fifth grade science curriculum', *J. Mater. Ed.* **27**, 217 (2005)
5. D.L. Leslie-Pelecky, G.A. Buck and A. Zabawa, 'Broadening middle-school student images of science and scientists at the fifth grade level', *J. Mater. Ed.* **27**, 173 (2005)
6. M. Meyyappan, 'Nanotechnology education and training', *J. Mater. Ed.* **26**, 313 (2004)
7. R. G. Jones, J. Kahovec, R. F. T. Stepto, E. S. Wilks, M. Hess, T. Kitayama, W. V. Metanomski, 'Compendium of polymer terminology and nomenclature', RSC-Publishing and IUPAC, Cambridge (UK), 2009
8. A. D. Jenkins, P. Kratochvil, and R. F. T. Stepto, 'Glossary of basic terms in Polymer Science', *Pure & Appl. Chem.*, **68**, 2287-2331 (1996)
9. *http://goldbook.iupac.org* . 'IUPAC Compendium of Chemical Terminology (the Gold Book)', XML on-line corrected version (2006-), created by M. Nic, J. Jirat, B. Kosata; updates by A. Jenkins, doi: 10.1351/goldbook
10. N. Skoulidis and H.M. Polatoglou, 'Integrated tool for the teaching of structural and optical properties of

nanostructures', *J. Mater. Ed*. **29**, 117 (2007)

11. D.-B. Shieh, C.-S. Yeh, W.-C. Chang and Y. Tzeng, The integration of biomedical nanotechnology education program in Taiwan, J. Mater. Ed. 29, 107 (2007)
12. W. Brostow, H.E. Hagg Lobland, S. Pal and R.P. Singh, 'Polymeric flocculants for wastewater and industrial effluent treatment', *J. Mater. Ed*. **31**, 157 (2009)
13. W. Brostow, T. Datashvili and H. Miller, 'Wood and wood derived materials', *J. Mater. Ed*. **32**, 125 (2010)
14. L.C. Klein, 'Implementing an undergraduate interdisciplinary concentration in nanomaterials science and engineering', *J. Mater. Ed.* **28**, 7 (2006)

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