Model of teaching integrative biology

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SUMMARY: The model of teaching integrative biology has been developed for the purpose of promoting biological literacy and the bio-centric world outlook among non-biologists. Within its framework, biological concepts are integrated into problem-oriented subjects. The teaching method is based on a non-standard interactive educational technique including dialogues, discussions, games and team work in small groups as strategies aimed at acquiring biological knowledge. The educational model developed is action-oriented. It incorporates biology into a system of vitally important knowledge and promotes environment-friendly mentality. The educational model has been successfully tested in secondary schools of Moscow with students majoring in economics and law. The results of the tests indicate that the students have become aware of the role of biology in their professional activities.

KEY-WORDS: biological literacy, integrative biology for non-biologists, educational model, interactive methods, team work

RESUME: Nous avons développé un model de l'enseignement de la biologie intégrative pour répandre les connaissances fondamentales biologiques parmi des non-biologues. Sur cette base, nous poursuivons le but de l'intégration des concepts biologiques dans des sujets instructifs liés aux problèmes concrets. La méthode d'instruction est fondée sur une technique innovatrice et interactive, qui inclue des dialogues, discussions, jeux et la résolution des problèmes par des groupes; cette stratégie sert à familiariser des étudiants (élèves) avec des connaissances biologiques. Notre model de l'enseignement de la biologie se concentre sur des actions pratiques. Il plonge la biologie dans un système des connaissances essentielles est convient a l'attitude protectrice envers l'environnement. On a vérifie le model avec succès aux écoles secondaires de Moscou en utilisant des élèves qui s'intéressent a l'économie et au droit. Les résultats de ces expériences témoignent que les élèves se sont familiarisés profondément avec le rôle de la biologie a l'égard de son activité professionnelle en avenir.

MOTS-CLES: connaissances biologiques; la biologie intégrative pour les non-biologues; model de l'enseignement; méthode interactive; résolution des problèmes par des groupes

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It is obvious that a new system of biological edicutaion for non-biologists is required to overcome biological illiteracy[1,2]. It is imperative that this system should address a major part of students, i.e. those intending to choose a non-biological career. It is to be significantly different from the educational system (including goals, content and approaches) for professional biologists. For this reason, the subject-content and presentation of integrative biology, a novel educational approach and attitude in terms of general scientific programme[3], should depend on the type of students dealt with. The concept of integrative biology currently under development[4], is aimed at the integration within biological disciplines for discussing scientific matters and facilitating the scientific training for biologists with diverse expertise and perspectives (biologists, scientists in general, and non-scientists)[5]. This approach seems to be attractive and potentially efficient in terms of the "biological education for non-biologists", and it should provide the foundations for this kind of education. However, the concept of integrative biology should be additionally expanded so as to satisfy the needs of non-biologists, because it should acquire an additional interdisciplinary dimension, providing integration of biology with other fields of science.

This paper deals with the results of our project concerning the focal points of the biological education for non-biologists and the development educational model to use for teaching integrative biology.

1. Integrative biology for non-biologists.

We suggest the following definition of integrative biology as an approach to teaching non-biologists.

Integrative biology is a system of biological knowledge integrated in conjunction with other knowledge in the field of natural sciences and humanities, into a complex system of human vital values for the purpose of developing biological literacy among non-biologists.

Following are the implications of this definition which are important in terms of bio-education for non-biologists. Integration of biology with other natural sciences and humanities provides for an interdisciplinary character of the educational approach. Biological knowledge with its interdisciplinary underpinnings is to be included into the system of vital values applying both to everyday life and professional activities of future non-biologists. On this basis, scientific knowledge takes effect, i.e. proves useful and provides for eradication of bio-illiteracy. This implies getting familiar with the fundamentals of modern biological knowledge and developing decision-making skills and accumulating practical experience in real-life situations and professional activities, in order do derive benefit from this knowledge.

2. The focal points in integrative bio-education for non-biologists.

In order to single out the problems and issues relevant to integrative biology in the aspect

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[1] Mikhail Gusev "From anthropocentrism to biocentrism" *Vestnic Moscow University*, Ser. Biology, N5, 1992, 71-77 (in Russian).

[2] Mikhail Gusev "Biology and political science: supercession of the anthropocentrism of the earlier social systems by a more viable "biocentrism". In Mikhail Gusev et al., Eds., *Proceedings of the CBE-IUBS International Meeting "Biology, humanities and education"*, Moscow, Moscow State University, 1997, 7-12.

[3] "Towards An Integrative Biology (TAIB) Program". *Biology International*, 37, 1999, 3-9.

[4] Talal Younès "IUBS: 80th Jubilee. Integrative biologists and the challenge of complexity". *Biology International*, 38, 2000, 1-2.

[5] Marvalee H. Wake. "Integrative biology: philosophy and relevance to education". In *Abstracts of International*

dealt with we analysed the materials of the CBE-IUBS Conference held in Moscow in 1997[6], secondary-level syllabi on biology and environmental science, and evaluated the results of a questionnaire sessions with teachers as well as with secondary-level students from Moscow schools[7] .

1.Why should we pay special attention to non-biologists.

For most students in Russia, the secondary school level biology is the last stage of bio-education in their life. At the university or college level, biology is studied only by those specializing in biology or medicine. Most of the students preferring a career in other natural sciences, humanities, technology, engineering or economics, do not deal with biology at subsequent stages of education. However, in the future, some of these people will become decision-makers in the fields of politics, law, economics, construction, social services, mass media, etc. They will make socially important decisions whose consequences are often quite unclear, and their potential after-effects are destructive for the biosphere and society. That is why we conclude that integrative biology teaching is primarily intended for senior secondary-level students, who have already made their decisions concerning the future professional career not related to biology or other relevant fields of science.

2. *What subject should non-biologists be taught.*

Available biology syllabi are aimed at imparting biological knowledge only. Most students perceive them as extremely sophisticated, useless and routinized, and they overemphasizes details. Biology and environmental science syllabi cannot help us overcome bio-illiteracy. They do not provide the foundations for the bio-centric world outlook[1,8] which implies equal rights (primarily, the right to live) of all forms of bios and an equilibrium should be maintained among all biological species on the Earth. Bios creates the conditions for it's own existence as well as for human beings as one of the biological species; currently, humankind poses the threat of an irreversible disruption of this equilibrium.

Hence, special syllabi for non-biologists are to be developed. These syllabi are:

(i) to awaken students' interest in biology;
(ii) to establish links between biology and everyday human needs and professional interests;
(iii) to encourage the students to take account of bios-affecting consequences of their decisions in various fields of activities.

3. Choosing appropriate teaching methods.

Based on our studies, ordinary schools typically rely on traditional methods such as narratives, lectures and exercises. Innovative, interactive methods are employed only seldom. Among these methods the cognitive and simulation games are particularly effective. These methods have to give the students a chance to accumulate situation-related experience. So it should be necessary to employ innovative, interactive methods providing for the efficiency of the teaching process and practical applicability of the knowledge acquired.

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[6] "Proceedings of the CBE-IUBS International meeting "Biology, humanities and education". Moscow, Moscow State University, 1997.

[7] Tamara Korzhenevskaya, Ludmila Pyvovarova and Mikhail Gusev "The CBE-IUBS Conference: new role of biological education". In *Mikhail Gusev et al., Eds., Proceedings of the CBE-IUBS International Meeting "Biology, humanities and education"*, Moscow, Moscow State University, 1997, 83-93 (in Russian).

[8] Agni Vlavianos-Arvanitis and Alexander Oleskin. *Biopolitics. The bio-environment. A bio-syllabus*. Athens,

3. The educational model

Based on the above conclusions, we are currently developing a model to be used in teaching integrative biology. This model has been tested with senior secondary-level students majoring in law and economics from two schools which were allotted as “trial grounds” by the Moscow department of education..

The model for teaching integrative biology consists of 2 modules (Figure). The 1st, theoretical, module is aimed at bringing the relevant knowledge across to the students by the teacher. The teacher activates pre-existing knowledge and adds new information in the field of biology and other related subjects. The 2nd, practical, module enables the students to acquire relevant skills and situation-related experience.

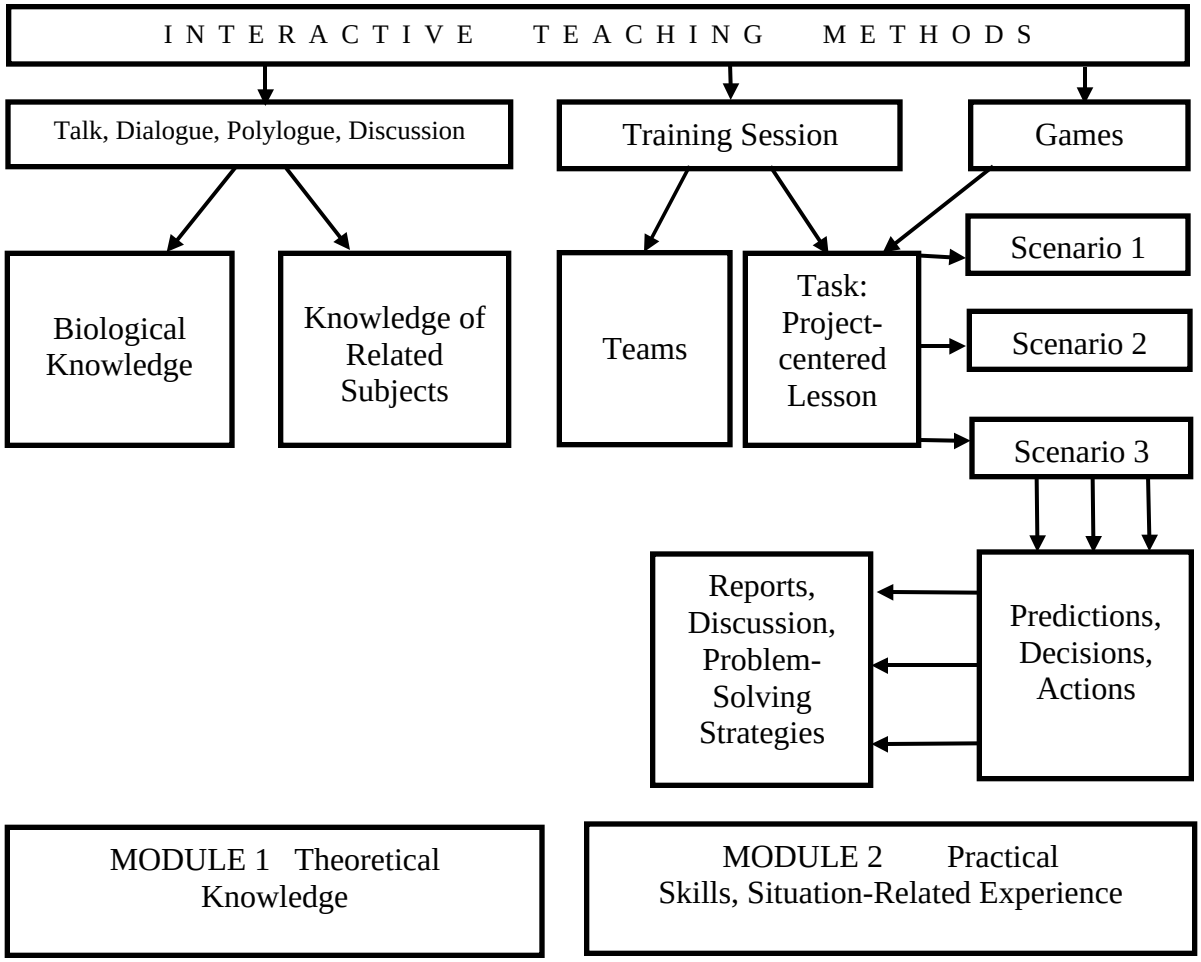

Figure. Model of teaching integrative biology

Both modules are based on interactive teaching methods. The 1st module includes talks, dialogues, polylogues, and discussions in order to achieve its goal. The 2nd module is based on combining individual efforts and team work. It makes use of training sessions, cognitive and simulation games.

Training sessions precede the whole work in terms of the educational model. These training sessions pursue the several objectives, such as:

(i) making up teams and recruiting leaders;

(ii) acquiring organizational skills and relevant cultural norms (formulating goals and tasks; looking for alternatives; argumentation and decision-making; carrying out discussions, etc.);
(iii) accomplishming of subject-related tasks by teams on biological or environmental topics.

The task itself is to be done in terms of a cognitive or simulation game and should be regarded from different perspectives. Each team is to consider one of the possible scenarios in terms of the task formulated. The students are expected to carry out the task, taking into account their future profession. To this end, the students are allotted different roles.

The last stage of teamwork deals with developing scenarios concerning biological/environmental problem. In these scenarios, the students should predict and discuss the consequences of human decisions, and suggest problem-solving strategies. In developing these scenarios, students should consider not only the benefits of the decisions and practical steps for humankind, but also their contribution to bios- and environment conservation-related tasks. During their work on the task, students develop bio-centric attitudes and acquire situation-related experience. As a result, biological literacy appropriate for non-biologists coping with a biological or environmental challenge is acquired.

4. Applying the educational model to classes on biological and environmental problems

In the terms of the model presented we worked out the topics for the lessons on different fundamental and applied problems in biology and environmental science.
Following are selected topics related to various sections of our syllabus.

1. Recent biological developments : predicting their impact on society and biosphere (transgenic plants; animal and human cloning; deciphering the human genome; aging mechanisms). Biological, medical, social, economic, bio-ethic dimensions.
2. Human responsibility in terms of preventing the real threat of anthropogenic crises. Comparison with the great catastrophes of the past.
3. Origins of life. Understanding life on Earth as an unique phenomenon in the Universe. Preventing its extermination.
4. Outcome of the Pre-anthropogenic evolution of life.
   4.1. Establishment and maintenance of the homeostasis of the Earth's biosphere by bios.
   4.2. Oil as a product of the bios forms at the early stages of biosphere evolution and a means to satisfy the needs of modern civilization. Economic, political and environmental after-effects of oil extraction and utilization.

Let us consider the applications of this model in the example of the topic: "Recent biological developments: predicting their impact on society and biosphere".

Stage 1 deals with recent biological developments including transgenic plants, animal and human cloning, the research on deciphering the human genome and ageing mechanisms. These developments have not yet been incorporated into current syllabi. The students acquire biological knowledge underlying these developments. In terms of the topic-centered lesson, the teacher discusses in general the potential applications of biological discoveries with the students. Based on this discussion, the students draw a number of conclusions. Satisfaction of human needs calls for developing new biotechnologies and economic projects. However, we are ignorant of the long-term bios-endangering consequences of employing new biotechnologies. These consequences should be evaluated in advance, in particular, we should provide legal foundation for bios-promoting policies which ultimately are vital for the existence of humankind *per se*. For this reason, one should modify the professional

requirements to be met by non-biologists. They are to become bio-literate and develop prognostic thinking, i.e. they should become able to forecast the consequences of their own professional decisions and activities related to practical application of scientific development.

Subsequently, we touch upon the question how one should predict this kind of consequences. For this purpose, we use (at Stage 2) an example which should be familiar to the students. This example is concerned with the discovery of radioactivity. This is an impressive example of dangerous applications of a scientific discovery. We discuss the consequences of using atoms for peaceful and military purposes. Disentangling the cause-effect relationships with regard to human-made decisions concerning uses of radioactivity and their consequences, the students should grasp the logic underlying those cause-effect concatenations and learn how to predict scenarios of this kind.

At Stage 3 of the lesson, the students are offered a project to be developed in terms of the team's work. Following is the summary of the results of doing the task on the subject of: "Forecasting the consequences of the practical application of hypothetic method of prolonging human life-span to 150 years". In this game teams were to make their predictions, considering the problem in the realistic, pessimistic and optimistic viewpoint.

The students engaged in disentangling the cause-effect relationships relevant to the application of a scientific development and its consequences. Increasing the human lifespan would result in an increase in the human population. This would cause economic, political, social and environmental concerns. The students mentioned the industrial production increase, natural resource depletion, food problems, unemployment, wars for resources and territory, environmental pollution and other problems. From the results of students' deliberations it is evident that the negative consequences (emphasized by pessimists) can in principle be offset by other, useful after-effects (stressed by optimists). For instance, the natural resource depletion-caused economic and political problems (including wars) can be overcome by resorting to alternative energy carriers. Moreover, the very necessity of coping with economic problems can precipitate important measures promoting international cooperation. However, the studies made by our students revealed that, if the Earth is overpopulated, there will be no reasonable alternative to protecting and promoting biosphere at the modern civilization level. Biosphere-related issues result from environmental pollution, displacement of some species from the natural habitats, destruction of natural ecosystems and some other reasons. This inevitably results in a qualitative and quantitative impoverishment of global bio-diversity and, accordingly, to an imbalance in biospheric processes and a threat to the very existence of life.

As a result, the students reveal numerous positive as well as negative relationships between the biological problems and those of human beings, society, environmental and biospheric processes. They become aware that the fate of the scientific development and the fate of life on the Earth will depend on human decisions and activities. It is essential that they should be guided by bio-ethical norms. The students are familiarize themselves with the role of biology in their every day and professional activities and realize that biological knowledge is a necessity and also a catalyst of their life-competence.