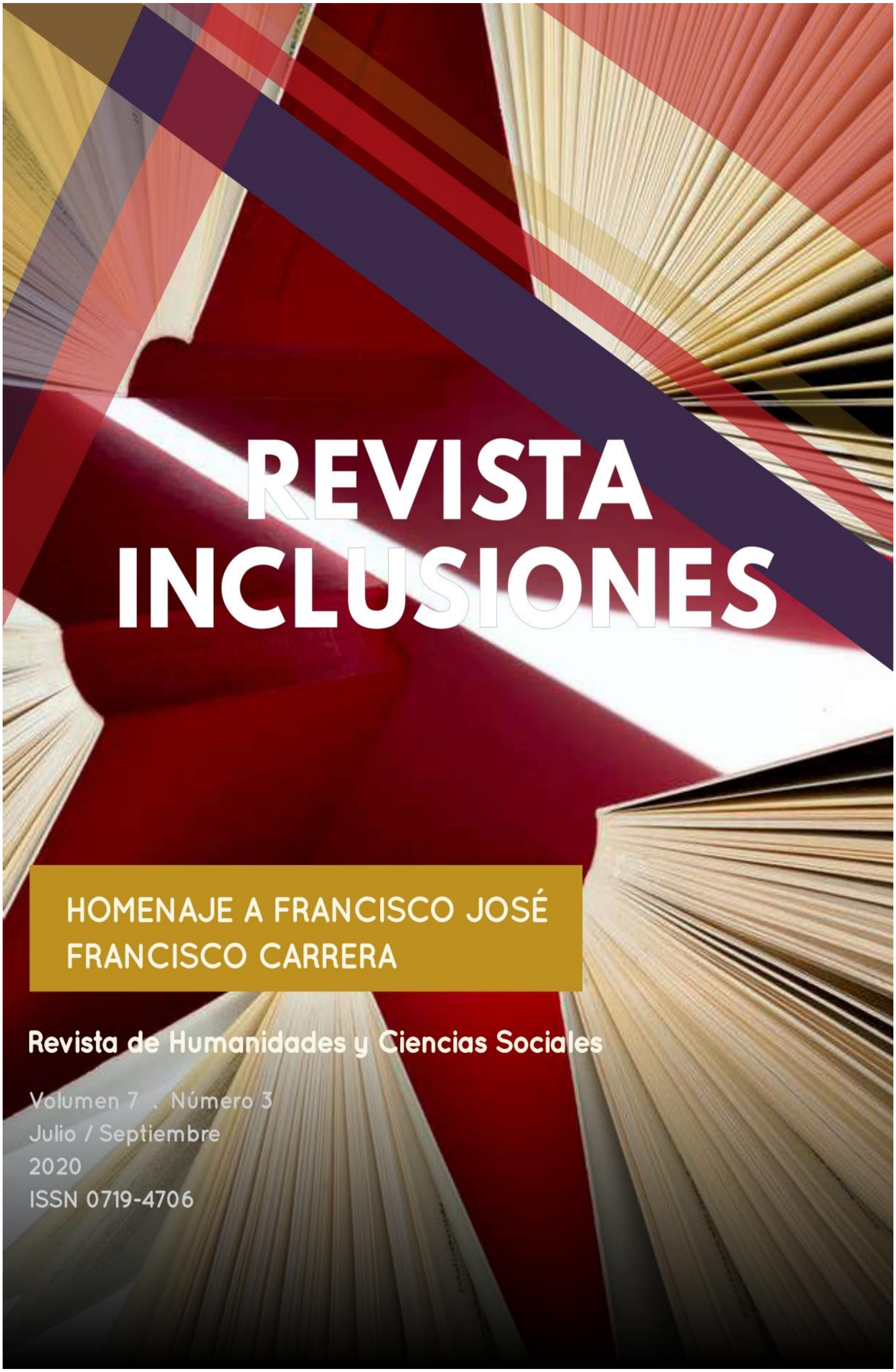

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FORMATION OF SYSTEMATIC KNOWLEDGE IN SCIENCE STUDENTS IN HIGHER EDUCATION

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Abstract

The study deals with the main issues of developing systematic knowledge in students within higher education and provides possible solutions. A scheme of systematic approach stages is proposed. Particular attention is given to examples from pedagogical practice.

Keywords

Higher education – Scientific knowledge – Systematicity – Systematic approach

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Introduction

In Russian Federal State Educational Standards (FSES) of all fields of study particular attention is given to the development of general professional and vocational competences. However, it is impossible to form professional abilities and skills without knowledge. Students obtain knowledge during classwork, as well as individually, and the hours in the curricula are predominantly allocated towards the latter. Therefore, teachersneed to draw up syllabi considering all theprinciples and requirements. The most important principle, in this case, is the principle of systematicity of knowledge. It denotes the process and the result of students' acquisition of concepts and sections in their logical connection and continuity[1]. However, not always or rather not only the systematicity of knowledge contributes to the formation of the final worldview.

In the current context, when the amount of knowledge has grown dramatically and there is a trend for further increase, there is a need for systematicity of knowledge in science and the ability to individually expand one's knowledge and navigate the flow of scientific information. As a result, students often possess a large amount of information but lack the system for its understanding, processing and application.

Systematic knowledge is the knowledge that is arranged in the human mind according to the pattern: the main scientific concepts – the main scientific principles – conclusions – additions.

While using similar-sounding terms systemicity and systematicity, it is important to differentiate between them. Systemicity is the quality of a certain complex of knowledge that indicates that there are structural connections in a student's thought process that correspond to the connections inside the scientific theory. Systematicity is the quality of knowledge that reflects the presence of content-logical connections between individual components of knowledge[2]. However, only this factoris not enough for the development of thesystematic knowledge. To consciously understand the connections inside the scientific theory, one must understand the relationships between the main principles of the theory – its premises and conclusions that arise from the theory, between scientific facts and ideal objects. The lack of understanding or knowledge of structural connections inside theoretical knowledge leads to disruption of the logical sequence when studying laws and definitions that are derived from them, which will undoubtedly affect the quality of education.

Within the course of middle general education, a person obtains the fundamentals of sciences which is the knowledge that has the same contents and type of relationships as scientific knowledge, but differs in profoundness. Therefore, the fundamentals of scientific knowledge that are obtained there build the foundation for the development of a conscious logical understanding of the theoretical and practical levels of science in higher education institutions.

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[1] L. Ya. Zorina Didaktiches kieosnovy formirovaniy asistemnostiz naniistarshek lassnikov (Moscow: "Pedagogika", 1978).

[2] L.Ya. Zorina Didaktiches kieosnovy formirovaniy…

Methods

The object of this study is the process of the development of systematic knowledge. Within the study, we utilized questionnaire methods, including conversation and testing, that are a sociological research instrument.

We studied regulatory and legal documentation, as well as psychological and pedagogical methodological literature, to establish how well-researched the issue is, considering both theoretical and practical achievements.

Using the method of analysis of psychological, pedagogical and methodological literature, we analyzed the work of researchers and their practical experience, which allows us to identify various points of view on the problem of the study and ways to solve it. We analyzed more than 20 literary sources on the development of systematic knowledge in students in general secondary schools over the past five years. We could not find works dedicated to the study of systematic knowledge in higher education, which would serve as an incentive to conduct this study.

Results and discussion

Today’s realities show that very often schools coach students for the Unified State Exam (USE) and the aforementioned fundamentals are not formed. Thus, when school-leavers enter a university, they have separate factual knowledge and can sometimes apply it but cannot see connections between different elements of knowledge. For example, most school graduates show decent results and even can solve problems, when studying Mendel’s laws in the General Biology course. However, the question about the difference between inheritance and heredity is baffling to them. They don’t realize the hierarchical connections between premises and conclusions. The goal of higher education is to provide such knowledge and to form such competences that a specialist receives a full spectrum of knowledge on nature and learns the ways of obtaining, remembering it and the rules of its structuring.

To do this, the pedagogue needs:

- identify a complete object to learn a content “unit” of science;

- learn about the particularities of presenting the object during the education process;

- determine the type of conditions and means for systematic learning about the object.

However, it is difficult to choose a complete object. It is not a single scientific concept or a system of concepts, rather a scientific theory that has structure and consists of foundations and conclusions. Foundations are a part of a theory that encompasses themain concepts, initial premises and the basis. Conclusions are the part of the theory that is based on concepts and explains and predicts new facts. Since the first part is thoroughly covered at school, it is the goal of higher education to provide insights into the second.

Another important point for the formation of connection in science is understanding the difference between science and a subject. A subject is a system that includes scientific knowledge and means for learning that fosters personal development (pedagogical and educational). Thus, the teacher's didactic goal is to find efficient ways of learning what would help create a specialist with a comprehensive scientific worldview. Therefore, to achieve this comprehensiveness, one needs systematic knowledge of science.

During the implementation of the systematic approach, one uses a gradual introduction of new information (Figure 1).

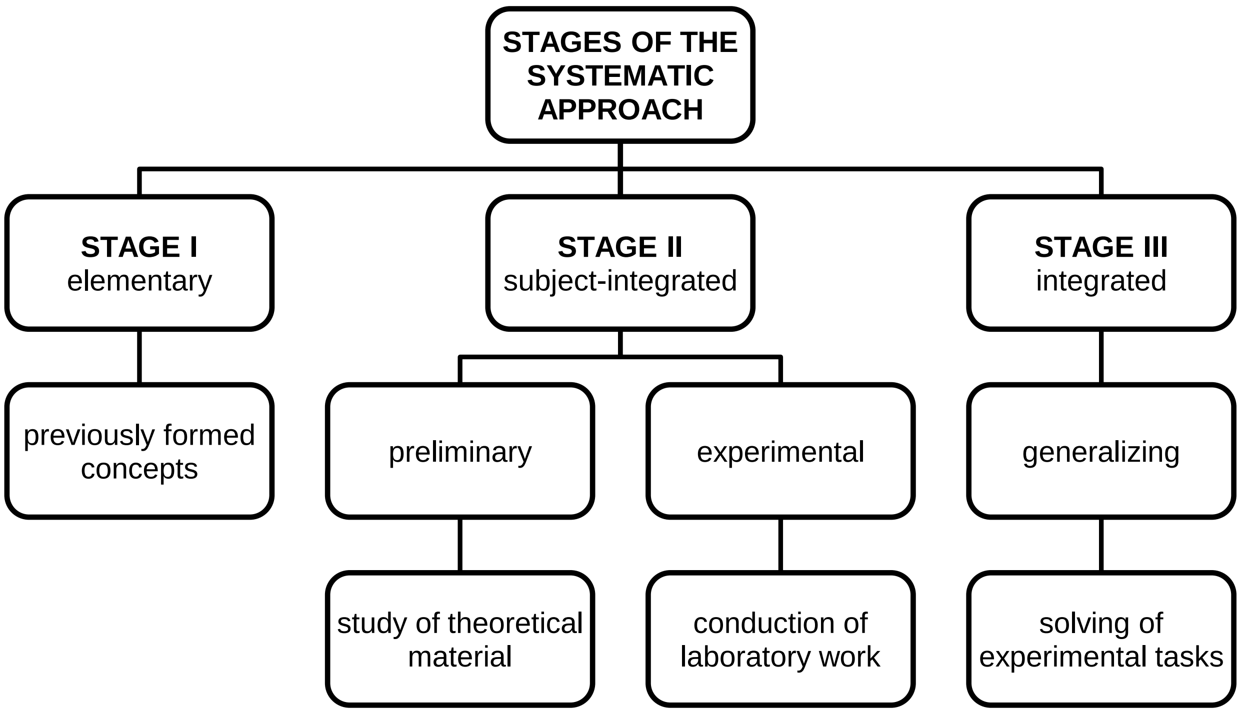

Figure 1
Stages of the systematic approach

Regardless of the field of study, the systematic approach guides the teacher in higher education towards the need to organize the learning process in such a way that the key role is dedicated to the student's individual cognitive work.

For example, when studying the branch "Kinetics" in the course on physical chemistry, the supporting concepts to form the notionabouta chemical reaction rate are master kinetic equations, the influencing factors for the reaction rate (concentration, temperature, surface area, etc.) and mathematical equations. This knowledge should be structured in a certain way in the student's mind (stage I).

Stage II is the main stage, and it is characterized by the subject-integrated approach. The first part of the II stage (preliminary) involves studying new material where the teacher provides theoretical material that serves as the basis. The material also includes the student's individual work with additional literature and, as a result, new concepts are formed. The systematicity of previously received knowledge helps the student correlate the new information (simple and complex kinetic reactions, the order of reaction, integral and differential equations used to determine the order of reaction) with the previously obtained basic knowledge, thus organizing the process of creating new knowledge. In the second part of stage II, the student should know how to establish connections between separate elements to do the matching of the new information to the system of previous knowledge. During this stage, the student performs several laboratory works. For example, to establish the connection between the elements of theoretical material on the concept of the reaction rate constant, there is a laboratory class to determine the reaction rate constant for saponification of a compound ether, study the connection of the reaction rate from temperature and calculate activation energy and the constants in the Arrhenius equation[3]. The activation energy and the constants in the Arrhenius equation are calculated based on the experimental data in two ways: the analytical and the graphical way. Thus, the efficiency of the systematic approach is implemented well during laboratory work when solving experimental problems.

Stage III (final) includes the generalization of knowledge and implies the implementation of combined tests on the section including control, both in the form of a test and solving experimental problems. The difficulty level of these tasks should be such that the student could solve them using the previously acquired knowledge.

At the final stage, the systematization of knowledge does not stop, since as a result of activity the process goes on continuously, and self-education, self-development and self-improvement take place. This example reflects the application of systematicity within the framework of one topic but thefurther development can be carried out in the formation of knowledge on the scientific theory.

The scientific theory is a special form of organizing scientific knowledge that consists of the following elements: scientific concepts, laws and facts. The type of connection between them is determined by their place within the theory. The scheme of element connections is varied and does not depend on how it is unfolded. However, the key property of the theory is systematicity. The students' acquisition of theoretical knowledge should lead to the development of the true scientific worldview that is latertested and confirmed through practice.

Let's say, the knowledge of the structure and functioning of animals, as well as their classifications and taxonomies, allow thestudents to later use them for explanations of ecological and evolutional processes. The system of knowledge on patterns of the structure of multicellular animals is comprised, above all, of concepts formed within the school biology course (for example, development, organs, organ systems).

When teaching a university zoology course, we believe it is necessary to devote particular attention to comparative-anatomical, phylogenetic and evolutionary aspects rather than specific examples of the (internal and external) structure of certain animal groups. This enables one to view the animal world as a single system that is not just the sum of its parts but is comprised of interconnected elements.

It is possible to build knowledge on the variety of the animal world from the perspective of a germ layer theory. The study of multicellular animals starts by introducing

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[3] E.I. Smetanina y V. A. Kolpakov, Laboratornyipraktikum po fizicheskoikhimii: uchebnoeposobie. Tomsk Polytechnic University (Tomsk: Izd-voTomskogopolitekhnicheskogouniversiteta, 2012).

notions concerning body layers (the ectoderm, the endoderm and later the mesoderm), as well as organs that form from these layers during theembryonic development. This, in turn, is closely connected with I.I. Mechnikov's theory of "parenchymula" – the common ancestor of all multicellular animals.

The development of the system of ideas on a certain origin of organ systems can be traced, for example, when studying the phylum Coelenterata. In the theoretical part, thestudents obtain knowledge on ectoderm and entoderm as layers of the body. In this case, the nervous system is viewed as part of the outside cellular layer (the ectoderm), although its cells can have an endodermal origin. Later, when studying triploblasty in animals, it is emphasized that the notion applies to the particularities of embryonic development and the formation of organ systems from certain germ layers. At the next stage, when studying the phylum Flatworm, the students come across the fact that different organs of the same system can have different origins (for example, ectodermal foregut and endodermal midgut). After that, the structure and functioning of organ systems in invertebrate animals are viewed in connection to their origin. It is pointed out that the system of organs within the same phylum may possiblyhave different origins. For example, the excretory system of terrestrial arthropods (the Malpighian tubules) can have endodermal (Chelicerata) or ectodermal origin (Tracheata). The structure of various organ systems can be viewed in the same way while studying vertebrate animals including humans.

Therefore, during lectures the students obtain the system of knowledge on the internal and external structure of animals of certain systematic groups and generalize this knowledge during theirindividual work and preparation for laboratory classes. The students develop not only the system of ideas on the germ layers and their derivatives within a single group of animals (vertebrates), but also on the fact that during the evolutionary process the germ layers became specialized over time, maintaining the ability to interchange the organs that they formed for a long time. The students are able toconclude that, despite being anatomically different in a significant degree, many systems of organs share the origin from the same germ layer.

As a result, by the end of the zoology course, the student has formed a system of ideas not only of the structure of a certain organ system but also of their development. The students obtain thesystem of knowledge and the skill to apply this knowledge to be able to explain evolutionary processes.

It is worth noting that the systematic approach makes it possible to form systematic knowledge within a subject. For example, when studying human anatomy, one needs to clearly set goals aimed at systematicity in learning which contributes to the formation of a comprehensive idea of the human body.

When one views the human body as a single biological system, it can be said that it consists of interconnected structures, namely cells, that in turn form tissues that comprise organs. Each organ has all types of tissues, but only one tissue is believed to be calledprincipal. For example, the main function in kidneys and glands is carried out by the epithelial tissue, the main function in the brain is ensured by the nervous tissue, etc. At the same time, the epithelial tissue covers mucous and serous membranes, and it is what the skin consists of. The epithelial tissue serves as a support for every organ (i.e. it forms the stroma) and performs the trophic function, the muscle tissue is part of walls of blood and lymph vessels, organs of the digestive system, airways and the urinary tract and the nervous tissue forms ganglia and nerves in the organs. Consequently, we could say thatthe organs comprise physiological systems that perform the same function. Some systems unite to form an apparatus[4]. Therefore, the study of anatomy should begin fromlearning biological notions related to the general structure of the human body.

The rest of the anatomy course is based on consecutive consideration of topics that allow one to view a system of organs, on the one hand, as part of the human body and, on the other hand, as a whole.

The first section deals with the structure of the musculoskeletal system. This topic is based on the information that ispreviously obtained, while studying bone and muscle tissues, when the students expand and enhancelearningaboutwhat the structure of bone and muscle as organs isand abouthowbones connect and howmusclesoperate. At the same time, during the consideration of this topic, one forms a comprehensive idea about the corresponding systems of the body and solidifies the knowledge of the key biological notions.

The next part of the second section is internal organs, where a particular organ in every system (digestive, pulmonary, genitourinary) is studied from its macroscopic to microscopic structure, i.e. from what is general to what isspecific. However, it is also constantly shown that microscopic structure is an integral part of the whole system, without which it simply cannot function.

The next section, the study of the vascular system, is also covered comprehensively, as a combination of interconnected elements, which makes it possible to understand the particularities of interactions not only inside the system, but also with theother systems. For example, the heart ensures that theblood flows into blood vessels that supply organs of other systems. In this case, the heart is understood asan integral part of the whole body, whereas its microscopic structure is an intrasystemic element that ensures contractions and that theblood flows inside blood vessels.

The nervous system and the sense organs have the most complex structure and organization. For every part of the nervous system, the students study the macroscopic structurefirst. They begin from the spinal cord, because it forms at the early stages of embryonic development, then proceed to study regions of the brain and sense organs. Moreover, this section shows the continuity of knowledge about the nervous tissue that is studied in the histology course, which makes it possible to obtain a comprehensive idea about the microscopic structure of theorgans. Furthermore, we could noticethatthe interaction of nervous structures and their influence on other systems that together maintain regulation of the whole body is another integral part of studying the nervous system and sense organs.

Therefore, the systematic approach to learning anatomy makes it possible to solidify the idea of the main biological notions (cell, tissue, organ, system, apparatus) and shape the knowledge of the common patterns and particularities in the structure of the human body.

[4] M.R. Sapin y G. L. Bilich, Anatomiya cheloveka (Moscow: Vysshayashkola, 1989).

Conclusion

Any subject can be viewed as a system, where the whole is comprised of interconnected elements (blocks)[5] but the main objective of the systematic approach appliedtothe higher education of Science students is the interdisciplinary connection of knowledge that helps to train a specialist, who has mastered the whole set of competences. This interdisciplinary approach is implemented during the whole course of thestudy, however, it is particularly evident once students have accumulated considerable knowledge. To implement the systematic approach to learning subjects within the system of higher education, it is important to correctly distribute the number of blocks, their volume, contents and status. Not any block can be the main one. Too many content blocks can fragment the material, undermine the integrity of the system of learning the subject and make it difficult to detect inter- and intradisciplinary connections. Too few blocks can result in some blocks being absorbed by others, so the systematic approach to learning the subject is distorted as a whole. The use of these methods for teaching requires a lot of work and commitment from all the participants of the educational process. The teacher creates curricula, tasks within the blocks of the learning process, directs, coordinatesthe students towards working and learning, consults, checks and assesses the result. The individual work of suchstudents increasesin volume, however, it should not remain without supervision. When one sets exact tasks for a student, there is a clear order of didactic units due to the systematic approach to teaching. When individual work is organized correctly and there is constant monitoring, then this model of education is going to besuccessful.

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