Information-object Approach to the Preparation of Educational Questions of the Subject Area

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Keywords: Information-object approach, Educational questions, The Minto pyramid principle, Teaching students to make questions.

Abstract: Educational questions have a high didactic significance for the teacher and the student. At present, preparation of questions practically has the character of an art, which determines the relevance of the formalization of this process. Of particular interest is to study and model accessible and instructive methods of composing educational questions for solving educational tasks, which was the goal of the work - to substantiate the information-object approach to the preparation of educational questions of the subject area based on the pyramid question method, the object's information model, and the concept of information entropy. The basic approach includes the technique of creating mental maps and a questions' tree based on the Minto Pyramid Principle. Formulations of questions are chosen from situations of uncertainty, covering a subject or section. Estimating the complexity of the question is carried out with the help of informational entropy. The described method was tested during the training of future teachers at KSPU named after V.P. Astafiev. The expert survey showed a high assessment of the didactic qualities of these questions. This approach can be useful for the development of electronic resources of the inverted type (question-answer format), as well as for the development of computer quizzes.

1 INTRODUCTION

The study and modeling of the ways of questions preparation can enable using them purposefully and effectively in the learning process, self-control and diagnostics of knowledge. The use of didactically right questions covering a topic, section or academic subject, for example, in game quizzes, causes cognitive activity in students, increases motivation for learning and cognition in general. Educational questions have a high didactic significance for the teacher and the student. However, at present there is no theory of the composing questions in terms of their didactic potential. In this regard, it is of interest to study and model accessible and instructive ways of compiling educational questions to solve educational problems.

It is important to determine the ways of compiling "right" questions from the point of didactics. Wrong questions can cause insecurity, irritability and may reduce motivation for learning. Right questions should determine the possible answer, motivate to search for and obtaining the right answer, be the standard and guideline in questioning learning.

Despite many publications and studies, the problem of teaching students to ask questions, build questions that motivate learning remains relevant and useful.

The purpose of the work is to substantiate the information-object approach to the preparation of educational questions for organizing training and

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diagnosing knowledge of the subject area based on the pyramid question method and information theory.

2 LITERATURE REVEIW

It is important for any person not only to answer, but also to be able to ask the right questions. Questions are the most important part of communication, they allow you to understand the interlocutor, to learn, to delve into the essence of the educational material, to separate the main from the secondary. The problem of teaching students the ability to ask questions has long been noted by teachers and scientists in the field of education (Pototnya and Firsova, 2018; Donskih, 2018; Hanif, 2022). This fact is due to the fact that by requiring students to ask questions, we are trying to encourage them to independently immerse in the educational process, to eliminate the passive way of perceiving information (Seregin, 2012). However, it is unfair to require students to correctly formulate and ask questions without providing the appropriate conditions or learning environment (Akimova, 2019). Indeed, for example, a child learns to walk in an environment where everyone walks, a first grader learns to write and read in an environment of letters and signs. The teacher should also build the learning process using a problem-question form, where questions are not asked formally to identify the level of assimilation of information, but in such a way as to encourage the student to further comprehend the material being studied. The most difficult for students are creative and practical questions (Palinsar and Brown, 1984). However, if students manage to master the technique of using questions, they begin to ask them in a wide variety of situations (Halpern, 2000).

The question format of the presentation of educational material, causing a situation of uncertainty, generates interest in getting an answer, it is practice-oriented through self-mastery of knowledge. So, for example, considering the topic "Information encoding", in addition to the questions "How to encode textual information?" and other questions will involuntarily arise: "Why is it necessary to encode information in various ways?", "Where is the N method of encoding information used?". Obviously, in the question format of training, students will involuntarily have their own questions. M. Bowker notes: «… questions helps students understand how the answers we have come to accept are connected, contingent, and contextual, how they rely on, imply, and beg additional questions. In this question-centered pedagogy, the questions themselves are the answers» (Bowker, 2010).

Furthermore, the question format for presenting educational material maximally meets the cognitive features of the digital generation - obtaining information in microdoses that have a finished form (the form of posts / blogs, etc.), the requirement for a clear understanding of where and why they will need this information (Ivakina et al., 2021), learning through gamification (Nikanov, 2020).

From the point of view of constructing a methodology for questioning learning, it is of interest to resolve situations of uncertainty and develop strategies for solving complex problems using the Barbara Minto pyramid principle (Minto, 2004). This method is based on the MECE principle (an abbreviation for Mutually Exclusive, Collectively Exhaustive - "mutually exclusive, jointly exhaustive"), which determines the procedure for solving a problem by creating separate non-overlapping questions related to the problem under consideration (Rasiel and Friga, 2007). The essence of the method is to select the main issue or situation, which are divided into a number of problems and tasks, which are further also divided into parts, until the breakdown leads to specific solutions.

Questioning education based on the pyramid principle in the context of the digital transformation of society can play a significant role in teaching students of creative areas of study, who perceive, for example, such disciplines as computer science, mathematical analysis, etc., as "unnecessary" subjects in their professional activities. Educational questions in the conditions of computer game situations can affect the successful formation of the student's digital intuition (intuitive understanding of digital technologies, the search nature of working) (Grohotova & Barkhatova, 2021). The combination of questioning education and gaming techniques in the process of teaching such students allows us to form an understanding of the essence of the subject being studied (Sidorenko and Pak, 2022).

Also, problem-question setting of tasks related to several subject areas allow to develop interdisciplinary competencies of students. In particular, they can be useful in STEM education. Among the many STEM skills are six fundamental ones: problem-solving, critical thinking, creativity, curiosity, logical-mathematical skills, engineering-design skills. Students can further develop their curiosity skills simply by learning how to ask the right questions. The right questions are likely to lead them to the right answers. In addition to problem-solving, critical thinking, logical-mathematical skills, it is also possible to effectively develop in the context of questioning learning.

Thus, the literature review shows a huge didactic potential of constructing education in a question-problem format: learning to ask questions, motivation to master the material in a situation of uncertainty according to the principles of microlearning, establishing interdisciplinary connections and developing an intuitive understanding of the subject. The implementation of this approach is possible using the Barbara Minto pyramid principle, which is the basis of our further research.

3 METHODOLOGY

The question is the creation of a situation of uncertainty. Uncertainty for a person can be instant, short-term or long-term. The answer to the question is the removal of uncertainty. The answer can remove the uncertainty of the question in part or in full. Also, the answer may have a zero result, and even a negative value (false information).

Uncertainty can be removed by a set of questions, which should be divided into complex-voluminous (thick questions) and simple (thin questions) (Fig. 1).

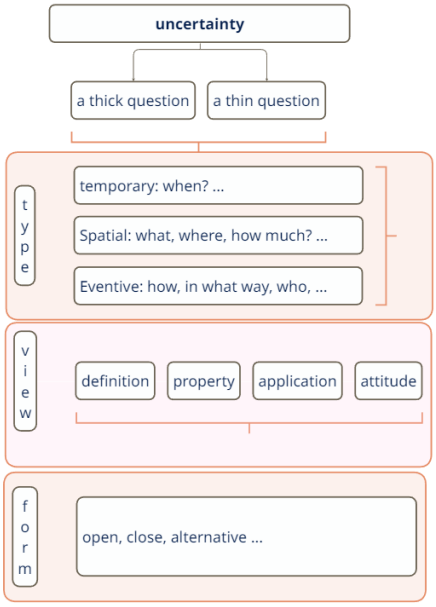

Figure 1: Classification of questions from the position of information-object approach.

The uncertainty of the environment is removed by creating an information picture of the world (Minkovich, 2018). Any object (material, conceptual) included in the structure of this picture can be described by its information model. As a rule, the information model of an object is determined by properties that reflect the characteristics of the object in spatio-temporal measures. Temporary measures capture the state of an object and its behavior over time. Spatial measures of an object (shape: length, width, height, color; quantitative characteristics: near-far, many-few, volume, area, etc.; kinesthetic characteristics: temperature, hardness, etc.) define its information data. Eventive measures define algorithms and patterns of object behavior, change of its states in time. In accordance with these measures, three types of questions arise: temporary questions (when? etc.); spatial (what, where, how much? etc.); event-related (how, in what way, who? etc.).

Each of the types of questions can be formulated in one of 4 types according to the structure of the information model of the object (Fig. 2).

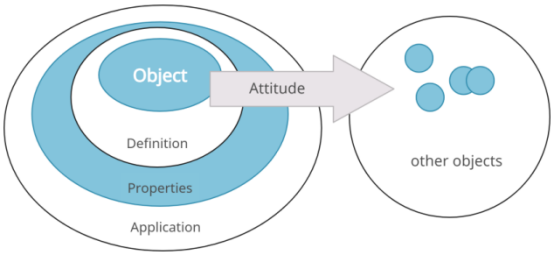

Figure 2: Structure of the information model of the object (concepts).

Questions cannot be separated from answers, therefore, question-answer forms of presentation should be defined as alternative (yes/no), with a choice (answer options that remove uncertainty, partially, completely), open (free answers), etc.

However, in this approach, the question remains, how to start compiling training questions on the topic under consideration?

It seems that, first of all, it is necessary to draw up a mental diagram of the topic of the subject area in order to visualize its knowledge model (Merrill, 2000). An example of a mental diagram for one of the educational topics of school geometry is shown in fig. 3.

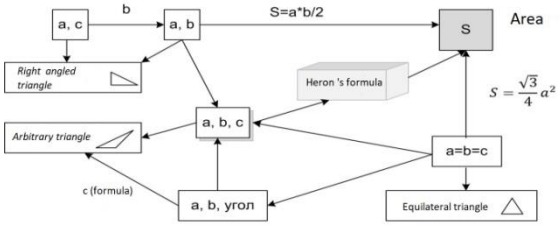

Figure 3: The mental diagram of the educational topic "Area of the Triangle".

The objectives of the scheme define an unambiguous fundamental question:

How to find the area of a triangle? The three schema conglomerations naturally define three sub-questions:

Sub-question 1: How to find the area of an equilateral triangle?

Sub-question 2: How to find the area of a right angled triangle?

Sub-question 3: How to find the area of a triangle on three sides?

Their further division into sub-questions will lead to the formulation of thin questions, according to the information models of objects and concepts of the mental scheme, as shown in the figures 1 and 2.

The scheme in Fig. 3 allows to compose questions according to an ascending strategy (“bottom-up”). In this case, thin questions are first formulated. They can then be integrated into thick questions.

Thus, the instructive algorithm for compiling questions of an educational topic can be represented as follows:

1. We develop a structural-mental scheme of the educational topic (plan-outline, mind map, etc.)
2. We build a tree of questions based on the structural-mental scheme of the subject area (topic, section) according to two strategies: top-down, bottom-up.
3. For each object and tree bonds (thick questions), we develop thin questions related to the definition, properties and use of objects.
4. The formulation of the correct educational questions of the topic should be associated with measures of time (when), measures of space (where, what, how much, what), operational measures (how, in what way), names (who).

In many cases, the uncertainty of the right questions can be measured by the information entropy of a particular person's intended answer. For example, in the question "In what year was the first ECM launched?" uncertainty for students studying the history of computing lies in the interval from 1920 to 1960. In this interval, the number of possible values (answers) is N = 40. Therefore, the information entropy, determined by the Hartley formula (Mogilev et al., 2016), is equal to H = log2 40. In another similar question, “In what century was the first ECM created?” the uncertainty is H = log2 2, because N= 2 (possible answers: 19th or 20th century).

4 RESULTS AND DISCUSSION

Therefore, it is advisable to compose thick questions using the Minto pyramid principle. The root question is the foundational question and is usually related to the topic of the subject area. Further, it is possible to construct a tree of sub-questions.

Breaking thick questions into sub-questions will lead to thin questions that require a clear and concise answer.

If you apply the strategy of creating questions "bottom-up", then you should start with thin questions, using the information model of the object or the concepts of the educational topic. An example of drawing up subtle questions on the mathematical object "triangle":

Definition

A geometric figure made up of three segments connected to each other is called? (triangle).

How many sides are in a triangle? (three).

What is the name of a triangle in which all angles are less than 90 degrees? (acute-angled).

Properties

What is the perimeter of the triangle? (sum of sides).

What is the sum of the angles of a triangle? (180 degrees).

Is the sum of two sides of a triangle greater than or less than the third? (greater).

The area of a triangle is half the product of the base and the height? (yes)

Is it possible to find the area of a right triangle if the legs are known? (yes)

Application

How many triangular slabs will be needed for a sidewalk of a given width and length?

How is the triangle related to other objects?

How to find the diameter of a circle inscribed in a given triangle?

Students of the Institute of Mathematics, Physics and Informatics of Krasnoyarsk state pedagogical university named after V.P. Astafiev were asked to develop questions for the course "History of Informatics". Compilation process caused great difficulties and low efficiency. Many students found questions on the Internet, because they could not cope with the task on their own. At the same time, the questions did not cover the entire subject section under consideration, questions were not systemic and were not suitable both for educational purposes and for diagnosing knowledge.

After they got acquainted with the approach considered in the work, the motivation changed

significantly, and the quality of the questions themselves increased significantly.

Below are snippets of thick questions compiled by students on some of the topics in the history of computer science course.

Questions:

Definitions

1. What was the prerequisite for the appearance of the measure of information?

2. There are two points of view: information is a product of the reflection of matter in our minds, i.e. outside consciousness there is no information; another point - matter itself contains information (latently), consciousness only cognizes it in the process of interaction. Where is there more truth and how has the evolution of these points of view taken place and is taking place?

3. What is the essence of the concept of "message?

Properties

1. If information is the properties of matter, then what properties should information have?

2. Is truth and falsehood an objective or subjective reality? What is the essence of relativity and evolution of truth and falsehood?

3. How did the transition from physical to informational entropy occur?

Application

1. When did the concept of artificial intelligence appear, how did views on this concept change?

2. Every message is a code. Why do we need codes to transcode codes?

3. What was the prerequisite for the creation of counting, measurements?

Attitude

1. Is the Internet an insight of human genius or an evolutionary result of the development of communication?

2. What are the historical roots of information security?

According to the proposed method, the authors compiled the textbooks “Learning to solve equations easily and simply” (the team of authors of KSPU, 2023) together with students, as well as “Combinatorial problems in computer science” (http://elib.kspu.ru/document/69420).

An expert survey showed a high assessment of the didactic qualities of these manuals for the development of schoolchildren and students.

5 CONCLUSIONS

The paper proposes an information-object approach to the preparation of questions, determining their complexity using information entropy. The approach to compiling educational questions based on the question method of the pyramid, the information model of the object and the concept of information entropy has a clear algorithmic and instructive nature. It facilitates the process of compiling educational questions for organizing training and diagnosing knowledge. The information-object approach is useful for the development of electronic resources of an inverted type (question-answer format), as well as for the development of computer quizzes.

To sum up, the proposed approach facilitates and formalizes the instructive algorithm for compiling educational questions in subject areas. The question format of educational resources allows not only to build educational material in a problematic form, but also to organize the educational process using the ideas of gamification.

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