Inquiry-Based Learning in the Study of Chemical Disciplines by Food Technologies Students

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Abstract: Inquiry-based learning, IBL is analyzed as an educational strategy in which students use research methods and practices It is noted that the advantages of IBL are the development of curiosity and critical thinking, as well as active, conscious and deep learning. The method of conducting laboratory classes in biochemistry for students of specialty 181 Food technologies is given. The purpose of the research project "Milk" is to provide a comprehensive biochemical assessment of milk as a valuable food product and to establish criteria for assessing its quality. The application of the IBL strategy allows you to catch up, deepen, expand and combine competencies in the main chemical disciplines. The implementation of IBL requires significant methodological efforts on the part of the teacher and a certain level of research skills and abilities of students. Therefore, it is obvious that this technique will be effective in the final classes of disciplines or in integrated courses. The development of thinking strategies, which are the essence of research practice, will be extremely useful in the performance of qualification work.

1 INTRODUCTION

New strategies and approaches to teaching with an emphasis on the use of multi-media resources are a trend in modern pedagogy. Since the middle of the twentieth century, the leading role in the study of natural sciences has been occupied by laboratory (practical) work. This involves direct interaction with equipment or materials, individually or in small groups, and includes observation and/or manipulation related to practical activities as well. Today, the method of conducting a lesson through the reproduction of a typical instruction by a student is becoming a thing of the past. The search and implementation of innovative methods and techniques in the educational process is relevant (Hulai and Kabak, 2022; Karnishyna et al., 2022; Oliveira and Bonito, 2023).

Based on a systematic review of the literature, Oliveira and Bonito (2023) state that the concept of a laboratory (practical) lesson often includes three big ideas: it should be an integrator of the manipulation of materials in practice; to develop competencies related to scientific processes aimed at a better understanding of the nature of science; to mobilize scientific knowledge in accordance with an approach aimed at awareness.

Inquiry-based learning, IBL is an educational strategy in which students use methods and practices similar to those used by professional scholars to acquire new knowledge. It can be defined as the process of discovering new cause-and-effect relationships, where the student formulates hypotheses and tests them through experimentation and/or observation (Pedaste et al., 2012). It is worth noting that the IBL is focused on students: what is new knowledge to them is not, in most cases, new knowledge to the world, even though scientists can flexibly use this approach in their discoveries of new knowledge (Pedaste et al., 2015). The method is used in teaching mathematics (both in high school and at university) (Cushman et al., 2023; Ernst et al., 2017), physics (Xaba and Sondlo, 2023), biology (Chen et al., 2023; Majidova, 2023), natural science (Camci and Büyüksahin, 2023), chemistry (Camci and Büyüksahin, 2023; Finn and Bradley, 2023; Ochs et al., 2023), foreign language (Lee, 2014), electronic technology (Hussain et al., 2023). Note the effectiveness of the application of IBL strategies in legal (Greenfield and Niemczyk, 2023) and medical (Finn and Bradley, 2023) education.

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Inquiry-based learning involves an intelligent challenge (Zohar, 2023). It develops curiosity and involves active, aware thinking, and deep learning related to issues of interest to students. Studies of foreign educators prove the benefits of Inquiry-Based Learning strategies to increase the level of emotional intelligence and psychological health of students (Sharma et al., 2023). Maharani et al. (2023) state the effectiveness of IBL tools for improving critical thinking skills. Paidi et al. (2023) effectively apply it in the study of biology to improve creative thinking skills and independent learning.

There are 4 main IBL techniques (Guido, 2017), which are perfectly illustrated by figure 1:

1. **Confirmation Inquiry.** The teacher gives students a question, the answer to it, and how to get that answer. Their goal is to develop research and critical thinking skills by learning how a particular method works.
2. **Structured Inquiry.** The teacher asks the students an open-ended question and suggests a research method. They should use this method to draw a conclusion supported by evidence.
3. **Guided Inquiry.** The teacher gives the students an open-ended question. Usually, in groups, they develop research methods to reach a conclusion.
4. **Open Inquiry.** The teacher only offers direction and provides students their own support. They ask original questions that they explore using their own methods and ultimately present their results for discussion and expansion.

IBL strategies are also not without some shortcomings and difficulties in implementation. With mass use, they can become superficial and formalized (Zohar, 2023). It's understandable that students who don't have the necessary thinking strategies and aren't used to applying them in their regular learning won't suddenly start using them when they switch to IBL. That is why, in our opinion, it is expedient to use this technology in the practice of university education.

The *aim* of the article is to demonstrate the practice of applying the IBL method in the educational process of Lutsk National Technical University on the example of conducting laboratory classes in biochemistry for bachelors in the specialty 181 Food Technologies.

2 METHODS

Based on the analysis of literary sources for implementation in the educational process, we chose the IBL structure described in the work (Pedaste et al., 2015). It includes five general stages: Orientation, Conceptualization, Investigation, Conclusion (Outcome), and Discussion (figure 2) and is non-linear in nature. The content and expected outcome of each stage are shown in table 1.

With the help of the arrows, three possible IBL trajectories can be traced (Pedaste et al., 2015):

(a) Orientation – Questioning – Exploration (the ability to return to the Questioning in a loop) –Data Interpretation – Conclusion;

(b) Orientation – Hypothesis Generation – Experimentation – Data Interpretation –Hypothesis Generation – Experimentation (the ability to return to the Hypothesis Generation in a loop) – Data Interpretation – Conclusion;

(c) Orientation – Questioning – Hypothesis Generation – Exploration – Experimentation – Data Interpretation – Conclusion.

All stages are united by discussion in different formats (student – teacher, student – student, group of students).

On the basis of this model, a methodology was developed and separate laboratory classes in the discipline "Biochemistry" were conducted for students of the specialty 181 Food Technologies of Lutsk National Technical University.

3 RESULTS

The educational program of the specialty 181 Food Technologies contains 5 disciplines of the chemical cycle, which are closely related, logically structured and aimed at forming the basis of professional competences. The IBL strategy is very well suited to the final topics of the course, dedicated to the chemical characteristics of certain types of food raw materials and products. Examples of the application of Inquiry-Based Learning in a workshop on chemical disciplines is shown in table 2.

Teaching biochemistry (a discipline that completes the cycle of studying the chemical foundations of food production) is based on the basic concepts and skills acquired in the mastery of general, inorganic and organic chemistry. In the laboratory practicum, the skills acquired in the classes in physical, colloidal and analytical chemistry are improved (Hulai et al., 2023).

Let's consider in detail the methodology of conducting a laboratory lesson on the topic "Milk" using IBL technology. The purpose of the study is to give a comprehensive biochemical assessment of milk as

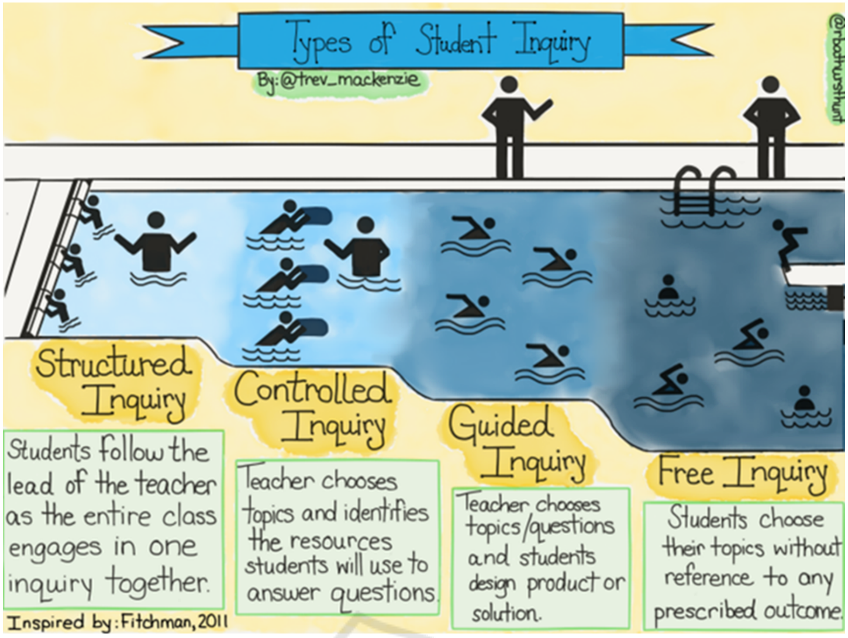

Figure 1: Basic techniques IBL (thinkingpathwayz.weebly.com, 2021)

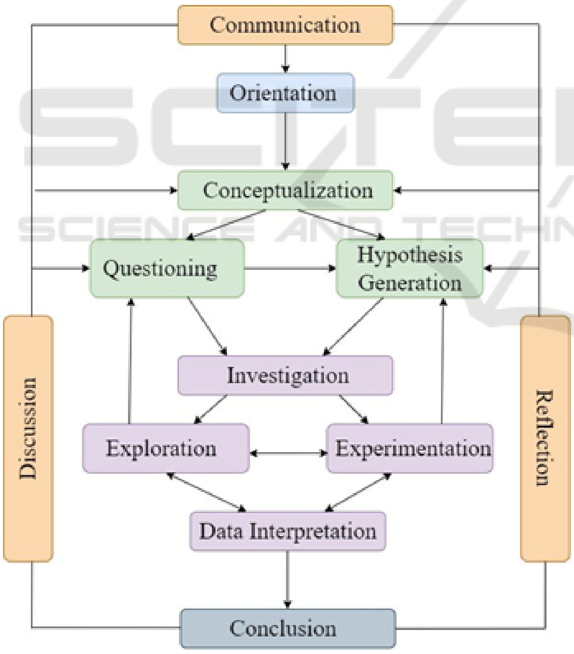

Figure 2: Inquiry-Based Learning Framework (based on Pedaste et al.) (Pedaste et al., 2015)

a valuable food product and to establish criteria for assessing its quality. In addition, students have the opportunity to catch up, deepen, expand and combine competencies in the main chemical disciplines.

Stage 1. Orientation. The teacher begins the lesson with a short discussion about milk as an object of study. The value of milk is due to the fact that it contains more than 200 different chemical compounds. The composition of milk includes all the substances necessary for the full functioning of the body: proteins, fats, carbohydrates, mineral salts, vitamins. These components of milk are well balanced, making them easy and completely digestible.

From a chemical point of view, milk is a polydisperse system that includes substances that are in different states: ionic-molecular (lactose, most mineral salts), colloidal (calcium phosphate, proteins) and coarsely dispersed (fats).

Stage 2. Conceptualization. It is clear that milk from different manufacturers and different degrees of freshness will differ in composition and properties of the pit. Therefore, students choose several samples of milk for comparison, for example, store-bought, farm and homemade. Divided into teams of 2-3 people, they determine the main research question (for example, how to establish the freshness of milk, its energy value, adulterated milk, macro- and micronutrients, etc.), find the necessary indicators from reference literature and Internet sources.

Stage 3. Investigation. Each team chooses methods (taking into account the possibility of using available laboratory equipment), draws up a research plan, prepares the necessary reagents and adjusts the devices. At this stage, the help of a teacher, as well as a qualified laboratory assistant, is especially important. Here are examples of experiments conducted by students.

To generalize and deepen knowledge of inorganic

Table 1: Content of Inquiry-Based Learning stages.

Stage	Definition	Result
Orientation	The process of stimulating interest in the topic and encouraging the solution of the learning problem.	Establishing the basic parameters of the subject area and formulating the problem.
Conceptualization	The process of asking theoretical questions and generating hypotheses regarding the stated problem	Formulation of research questions or hypothesis to be tested.
Investigation	The process of planning a search or experiment, conducting experiments, collecting and analyzing data based on the experiment design.	Interpretation of data (formulation of relationships between variables) that will allow you to return to the original research question or hypothesis and conclude on the assumption. Gaining new knowledge and forming skills and abilities.
Conclusion	The process of creating insights from data. Comparing conclusions drawn from data with hypotheses or research questions.	Final conclusion on the results of the study, answers to research questions or hypotheses.
Discussion	The process of discussing and presenting the results of each stage or the entire research to others (students, teachers) and gathering feed-back from them.	Reflection and discussion about the success and failure of the process, identifying ways to improve it and new inquiry for the next research cycle.

Table 2: Examples of the application of Inquiry-Based Learning in a workshop on chemical disciplines.

Discipline	Topic	Aim of the lesson
Inorganic Chemistry	Inorganic substances as food additives.	To investigate the properties of inorganic substances used as food additives, to study the principles of their labeling, to assess the potential impact on the human body.
Organic Chemistry	Food organic acids.	To study common food acids, to determine their content in food, to synthesize in laboratory conditions, to investigate resistance to aggressive factors.
Analytical Chemistry	Water quality.	To analyze the criteria for the quality of drinking and technical water, to determine the hardness of water of different origins, to study the effect of heat treatment, to establish the features of different types of mineral water.
Physical and Colloid Chemistry	Properties of emulsions.	To consider the types of emulsions and their application in food technology, to establish the physical parameters of the stability of emulsions (cocktails, sauces, etc.), to deter-mine the effect of stabilizers and emulsifiers.
Biochemistry	Milk.	To study milk as a biochemical object and the most important food product, to establish criteria for milk quality, the content of the main macronutrients in milk from various sources.

and physical chemistry, students can investigate the physicochemical properties of milk, in particular its density and freezing point. The density of milk is determined using a hydrometer. The density of milk varies from 1.026 to 1.032 g/cm^3. The density of skimmed milk is slightly higher than that of whole milk and can range from 1.033 to 1.038 g/cm^3. By the value of the density, it is easy to establish the adulteration of milk by dilution with water. Adding 10% water to milk will reduce its density by 0.003 g/cm^3.

The freezing point of milk is lower than the freezing point of water and ranges from -0.54 to -0.57 °C. The freezing point of natural milk is a constant value and this indicator can be used to determine its naturalness. The freezing point of milk is determined by the cryoscopic method using a Beckman thermometer. Every 1.8% of the added water lowers the freezing point by 0.01°C.

The study of milk as a colloidal system containing fat globules, casein micelles and whey proteins dispersed in an aqueous solution will allow a deeper understanding of the properties and behavior of colloids. In addition, the colloidal chemical properties of milk are the basis of many food processing technologies, such as cheese and yogurt. During the project, students investigate the coagulation of milk proteins under the action of acetic acid and acetone solutions of different concentrations. The acetone test is also a test for the freshness of milk, since milk proteins will only precipitate with an increase in the concentration of acids in the milk.

The acquired competencies in analytical chemistry are most used at this stage. The task of this discipline is not only to form students' knowledge of the theoretical foundations of the analysis of the composition of substances and compounds, but also to apply the acquired knowledge and skills of qualitative and quantitative analysis in professional activities, in particular to assess and control the quality of food raw materials. Therefore, first of all, we offer students to control the quality of milk for the content of inorganic preservatives, in particular, to investigate the qualitative content of hydrogen peroxide, chlorine and soda.

Determinations of hydrogen peroxide and chlorine are based on redox reactions of interaction with a starch solution of potassium iodide in an acidic environment. Molecular iodine, which is formed as a result of this interaction, gives starch a blue color. Soda in milk is detected by adding a 0.2% alcohol solution of rosoliic acid to it. The presence of soda is determined by the crimson-red color of milk. This task deepens the competence not only in analytical chemistry, but also in inorganic chemistry, since students need to make an equation for the redox interaction of hydrogen peroxide and chlorine with potassium iodide, select the coefficients by the redox balance method.

Determining the acidity of milk is an important aspect of controlling its quality and safety. High levels of acidity in milk can indicate that the milk is spoiled, and increased acidity in milk can affect its taste, texture, and nutritional value. Students use knowledge and skills in analytical chemistry, including using the acid-base titration method to establish the acidity of milk.

One of the teams conducts a biochemical analysis of milk, determining the content of carbohydrates (usually milk contains lactose, so it is interesting to check lactose-free milk), proteins (in particular, caseins) and fats.

Stage 4. Conclusion. At the end of the experiments, each team processes the results, evaluates the obtained indicators and compares them with the initial hypotheses. Draw up a report and prepare presentation materials.

Stage 5. Discussion. The class begins with introductory communication at the first stage, individual and group discussions, clarification of critical points at stages 2-4 and the final discussion. Since each team worked relatively autonomously, researching its own issue regarding the quality and properties of milk, the final discussion of the results is very important. Students demonstrate the results of experiments, methods and tools that they used to get answers to the questions posed, compare the results obtained by different methods.

The final element is reflection – answers to several questions about the lesson and your own achievements (questionnaire on the discipline page on the Moodle platform). It is important to analyze failed experiments or questionable results.

According to the results of a survey of students (20 2nd year students majoring in 181 Food Technologies of Lutsk National Technical University, 2022/2023 academic year), a positive response to the implemented methodology was established. Thus, 90% of respondents noted that they were interested in the lesson, 75% had to recall information from previously covered subjects, 85% learned about new facts and methods. Students identified the positive factors of the IBL methodology: dynamism, "never to be bored" (95%), the advantages of teamwork (80%), the ability to choose one's own research trajectory (65%), professional direction (75%), and the need to think hard (55%). However, 25% of students indicated that this method is too difficult for them compared to performing laboratory work according to the instructions.

4 CONCLUSIONS

Inquiry-based learning, implemented at the laboratory lesson in biochemistry, was positively assessed by both students and teachers of LNTU (low representativeness of the sample is associated with a small number of students in this specialty). It is worth noting that the use of the IBL method involves careful planning of the scenario and requires more time than traditional laboratory work according to the instructions. In particular, the methodological development described above was implemented during two 90-minute sessions, and the final discussion on the results was held in a separate lesson. We agree with the opinion (Pedaste et al., 2012; Zohar, 2023) that learning strategies that engage students in scientific research that involve active thinking have a positive impact on the understanding of scientific concepts compared to instructional strategies that rely primarily on passive learning.

Focusing on the development of students' research skills makes practical work more effective. IBL strategies aim to complement the traditional manipulation of physical objects with the search for scientific ideas and data analysis. The application of IBL requires significant methodological efforts on the part of the teacher and a certain level of research skills and abilities of students. Therefore, we come to the conclusion that this methodology will be effective in the final classes of disciplines, or in integrated courses. The development of thinking strategies, which are the essence of research practice, will be extremely useful in the performance of qualification works.

One of the problems we faced in the application of IBL was the assessment of students' educational achievements. In the assessment, we tried to take into account elements (Oliveira and Bonito, 2023) such as general settings, physical context, the relationship between skills and knowledge, and how realistic and interesting the task is for students. However, it is quite difficult to assess the cognitive and practical results of each student's work. The methodology and evaluation criteria require further separate consideration. An evaluation system needs to be substantiated, the structure of which includes a set of strategies and tools specifically designed to allow the evaluation of a specific stage of practical work. This will be the subject of our further research and methodological development.

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