
Theoretical Inquiry-Based Learning Insights on Natural Science Education: from the Source to 5E Model

Džeraldas Dagys

Lithuanian University of Educational Sciences, Faculty of Education, Department of Education, Studentų St. 39, LT-08106 Vilnius, Lithuania, dzeraldas.dagys@gmail.com

Abstract. The article presents a theoretical inquiry-based learning (hereinafter can be called IBL) methodology insights on natural science education. Seeking for an answer to the questions such as when did inquiry-based learning first appeared, which educational philosophy it derived from. It examines on what principles inquiry-based learning is rested on. An overview of IBL models, introduced information on exploration levels. Revealing inquiry-based learning advantages.

Keywords: *inquiry-based learning, IBL model, exploration levels.*

Introduction

Relevance. Currently knowledge at school gets in, in a few different ways - through an image, sound, motion and a combination of a word and an image. Therefore, educational experts often raise a question – what impact can it make on students' learning? What influence it has on their skills? New technologies, the new generations of students and their representatives' peculiarity, enforce to revisit a teaching methodology and an opportunity to influence students'. New technologies determine natural sciences educational practice, opens up new possibilities for inquiry-based learning.

Informative, interested in knowledge and creative society formation does not only open up new possibilities, but also requires a new approach for teaching and learning. Multiplication of the information allows significant expansion of educational space. It also changes the traditional role of school: in informative society school conveys only a

small part of the whole information that reaches a person. School should focus not on the transfer of knowledge, but on the ability to assess, select, organize, apply and transmit it.

Information technology and digital infrastructure promotes the development of new methods and a better environment for teaching and learning. Technological innovation must be associated with creativity, development of ingenuity and also be included in the curriculum, combining it with strategic Lithuanian and European challenges in pursuit of the realization of smart specialization, developing technological and intelligence capabilities.

New information and communication technologies are changing the practice of physics teaching, an opportunity appears to perform not only real, but also virtual physics laboratory works. There are various definitions of virtual laboratory works. They can be interpreted as computer program that allows the learner to perform dynamic experiments on the computer screen (Bajpai, 2013). Scientific literature contains many virtual experiments characteristics: less time-consuming, more flexible, clean, fast, safe, experiments can be carried out, where it would not be possible under normal conditions (Dalgarno & Lee, 2010; Petersson et al., 2013).

Along the emergence of virtual laboratory works a new scientific problem appeared - what laboratory works (virtual or real) allows to achieve better learning results? Research shows that there is no simple answer to that question, which laboratory work is better. Both, real and virtual, experiments have their own advantages. Students should have an opportunity to perform both of these experiments (Nedic et al., 2003). Both experimental forms of activity require new scientific insights (Jaakkola & Nurmi, 2008; Winn et al., 2006). New problematic questions arise: how the new internet generation can be motivated by traditional physics laboratory works, which are carried out with traditional laboratory instruments? What is the new generation students approach to virtual physics laboratory works, their role in the learning motivation of physics?

Physics experimental activities in school distinguish themselves with group activities. While working in groups students can communicate, exchange information, provide assistance for each other. It is actual to investigate how real and virtual physics experiments promote students interpersonal communication.

In early childhood students already have to be able to identify simple problems and propose solutions. To discuss and address the mentioned problems, the students should be able to cooperate. Nature is a living laboratory, where real-life experience is acquired on your own and pupils are allowed to become active participants in the learning process. However, a lot of questions arise, because of the effectiveness of such a learning, what are the boundaries between the real and virtual exploration, what is more efficient in a concrete area or situation.

Research shows that it is not that easy to answer which laboratory works are better. Both real and virtual experiments have their own advantages. Students should have an opportunity to perform both virtual and real experiments (Nedic et al., 2003). Both of

the experimental forms require new scientific insights (Jaakkola & Nurmi, 2008; Winn et al., 2006). Off of these studies follows an assumption that inquiry-based learning, both virtual and real laboratory works, can have a positive impact on students informative skills. In assessing this assumption arose new problematic questions: what are inquiry-based learning studying principles, how to correctly apply inquiry-based learning? What is the difference between information perception process while using usual learning methods and inquiry-based learning?

Summarizing the above raised questions a scientific problem is formulated: what is inquiry based learning and what are its' realization models? Problem question highlights the object of the research: inquiry-based learning. The research problem determines the aim of the study: investigate what is inquiry-based learning and its' advantages.

Research tasks:

1. Reveal the essence and benefits of inquiry-based learning.
2. Identify information perception process differences between usual learning method and inquiry-based learning.

Research methodology

The research methodology is based on the constructivist theory of education provisions that supports the structured-coordinated research activities as an effective educational technology, which promotes a positive attitude towards natural science objects leading to the usage of acquired knowledge in various situations, encouraging active learning process on the basis of knowledge and experience. Furthermore, it is based on the realistic educational philosophy provisions, which claim that natural science reality is objective and cognitive.

Research method

According to the logic of the survey data is collected continuously (Žydžiūnaitė, 2007). In preparing the article comparative analysis, synthesis and modeling methods were used.

Theoretical basis

Inquiry-based learning (IBL) is a learning methodology, which derived from constructivism. The literature gives a few IBL models and they are primarily based on three key indicators, which describe the nature of the research: the initial level of knowledge, attention to the learning process and workload (in the class, throughout the course and

in life as a whole). All of the IBL models are identified according to the following criteria (Minner et al., 2010; Marshall & Horton, 2011; Levy et al., 2012): (1) the research approval, (2) the query structure, (3) directing the research, (4) research openness, (5) the research variations. Well-designed IBL environment can enhance students' learning experience (Goldston et al., 2010; Mountrakis & Triantakonstantis, 2012). IBL has possibilities to improve students' self-regulation skills, but the orientation of information assimilation must be provided at the beginning of the learning process (Kirschner et al., 2006; Goldston et al., 2010; Segedy et al., 2015). IBL roots are found in the teacher papers, who played an active role in the study of children learning, such as H. Lane (1875–1925), J. Dewey (1859–1952) and M. Montessori (1870–1952), also you can refer to J. J. Rousseau's (1712–1778) early ideas, J. Pestalozzi (1746–1827) and F. Froebel (1782–1852). These teachers had the same point of view to education, where learners' curiosity, imagination and a desire to communicate and ask is respected. IBL is a learner-centered learning, where critical thinking, problem solving and communication skills are of a greater significance than just providing knowledge (Eisenkraft, 2003; Goldston et al., 2010). IBL is multifaceted activity, where data and information is collected and then analyzed in different ways (Eisenkraft, 2003). IBL requires to identify prerequisites using critical and logical thinking and make decisions through compromise. IBL can take different forms – analysis, problem solving, discoveries and creative thinking activities. IBL was formed as a response to the traditional forms of learning, when students were required to simply memorize educational material overloaded with facts (Hmelo-Silver et al., 2007). This learning is inductive pedagogy, where success is measured by how well students develop experimental, analytical, creative skills and not based on their knowledge. Teamwork, self-learning and problem-solving skills can improve critical thinking, problem examination (Segedy, 2014). IBL efficacy was proved over the students' evaluation, when accurate and proper questions were formulated, clearly identified issues and requirements were given systematically, wrong-management concept was developed (Levy, et al., 2012).

IBL is based on four principles which are common to all modern learning theories:

1. Learning takes place through a constructive, science-based knowledge structures.
2. The purpose of knowledge transfer is directed towards the process which combines conscious and unconscious perception.
3. The circumstances in which knowledge is acquired and subsequently used must be set in the beginning of the academic period.
4. Knowledge must be constructed in a reliable and stable way, so that it could be used now and in a distant future.

Summarizing these principles it can be stated that the most important principle is the application of constructivism. Learning is a process of constructing new knowledge, structures and a creation of new connections (Quillian, 1966; Schank, 1982). It means that understanding has to be inferred from the experience and communication. Knowledge cannot be transmitted directly from one person to another, because each person

develops his knowledge structure through own, unique experience. Understanding has to be developed gradually through consistent establishment of knowledge structure. The second principle captures the direction of learning. In a certain cases learning can be consciously directed and monitored through meta-cognitive processes, but the actual appearance of knowledge structure change takes a place below the level of consciousness and is guided by subconscious processes that are trying to separate the meaning from experience (Leake & Ram, 1995; Anderson, 1983; Laird et al., 1985; Schank & Abelson, 1977; Berlyne, 1960). The third principle describes a learning context through the knowledge accessibility prism. This principle requires better understanding of existing theories (Brown et al., 1989; Greeno, 1989) and is based on the recognition that knowledge is gained from the context (Glaser, 1992; Schank, 1982; Chi et al., 1981). Knowledge structure depends on the context in which the learning process is happening. These links can be set later. The fourth principle captures the differences between declarative and procedural knowledge. To apply declarative knowledge a person must have procedural knowledge, in other words procedural knowledge leads to the emergence of declarative knowledge (Anderson, 1983).

IBL educational principles in practice are realized in 3 stages (table 1).

Table 1
Three stages using inquiry-based learning

Stage	Process	Activity
Motivate	Need of experience	The activity creates the need for knowledge, which occurs when the students apply the knowledge to succeed.
	Curiosity	Activities that may result in disclosure of a gap in experience or restrict the curiosity of the learners' understanding.
Construct	Observation	Activity in which the students acquire new experience by observing phenomena
	Communication	Activities in which the students receive direct communication, which allows you to create new knowledge structures.
Improve	Application	Activities that allow students to apply their knowledge in a meaningful way, it helps to understand that they are useful.
	Summary	Activities that provide opportunities for learners to reflect on their experience, the knowledge and the opportunity to update the information in their possession.

The first stage is motivation (Edelson et al., 2011). In teaching context it is important to correctly use students' motivation measures and direct them through skills or knowledge that students can apply. The second stage is the construction of new knowledge. The success of this step depends on the new knowledge structure in memory. Students construct new knowledge as a continuation of the existing practice, so they could add them to construction of new concepts and divide existing concepts, or create new links

between concepts. A material, which helps students to construct new knowledge may be existing practice, communication, or a combination of both these materials. The third stage is improvement. Activities that provide opportunities for learners to retrospectively ponder their knowledge and experience allows to update already existing knowledge, creates preconditions for development. Students see an opportunity to apply their knowledge in a meaningful way and it helps to understand that it is necessary, it gives meaning to them and motivates to learn.

A three-stage learning model was developed an applied in experimental activity. It is called 5E model (Engage, Explore, Explain, Elaborate, Evaluate). Unlike traditional models 5E model aims to encourage students to obtain concepts and principles from science-based experiments and researches. As a result students acquire not only content knowledge but also important cognitive process skills such as critical reasoning and problem solving. This model (Figure 2) consists of 5 learning phases – engage, explore, explain, elaborate, evaluate.



Fig. 1. 5E model

Each phase has a specific function and contributes to teacher chosen teaching model. This model was used to help to develop programs and later lessons according to them. According to Bybee (2002) this model reflects the meaning of students learning. This model seeks to improve students learning through realization of the main concepts, which they will naturally apply in problematic situations. This model requires structurization in problematic situations, then students can explore, explain, elaborate and evaluate it. This model is based on cognition, when students themselves present ideas, see the need of them and use them. This model is bundled with students' skills development.

The first recognized research of the nature inquiry-based levels were presented by Schwab (1962) and Herron (1971). Bell, Smetana, Binns (2005) later Banchi and Bell (2008) researched inquiry-based learning and identified 4 levels of it (table 2): approvable research, structurized research, coordinated research, open research. Inquiry-based learning levels differentiates in a creative activity complexity level. The least creativity

requires level 1, the most – level 4. The most simple first level is sometimes defined as a confirmation research. At this level students are aware of the question, work-flow and an outcome. Structured or so-called second level research students are aware of the question, work-flow but do not know the outcome. The third level research is different from the second one because students only know the question, but the work-flow and an outcome of the research students have to plan themselves. The fourth research level is the most complex: students do not know the question, work-flow or the outcome.

Table 2

Exploration levels according to Banchi and Bell (2008)

Exploration level	Question	The progress of the investigation	Expected result
1 level confirmatory research	Known	Known	Known
2 level structurized research	Known	Known	Unknown
3 level coordinated research	Known	Unknown	Unknown
4 level open research	Unknown	Unknown	Unknown

You can find different research level titles, including “traditional”, “guided research”, “structured research”, “open research”, “coordinated research”, “practical research”, “teaching of the research”, “directed research”, “authentic research”, “scientific research”, “partial research”, “complete research”. (Abraham, 2005; Anderson, 2002; Bell et al., 2003; Chinn & Malhotra 2002; Colburn, 2000; Domin, 1999; Eick ir Reed, 2002; Farrell et al., 1999; Gaddis & Schoffstall, 2007; Germann, 1989; Germann et al., 1996; Hancock et al., 1992; Martin-Hansen, 2002; Kyle, 1980; NRC, 2000; Mohrig, 2004; Mohrig et al., 2007; Pavalich & Abraham, 1977; Schwartz et al., 2004; Windschitl, 2004; Windschitl & Buttemer, 2000). The following terms have a lot of meanings. For example, in the literature you may face several definitions of coordinated research, which meaning may vary, depends on the author and publication.

If exploration of IBL levels is done with the approach of informative search, new aspects are revealed. While conducting confirmative research learners only experimentally verify already known information. In the research process the experimental process was analyzed not as an ordinary information searching (finding) cycle (2nd figure), when the question is known and the answer is sought through literature analysis. In the other level cases (2nd–3rd levels) (2nd table) the expected result is not known in advance.

Inquiry-based learning is being researched not only in terms of levels but in cycles also. Cycle approach is relevant in examining the search of information in inquiry-based learning. Researcher Exner (2014) brought up two main cases of the search of information in inquiry based learning. In the first case - a classic approach to the search of information (Fig. 2), which can be applied in inquiry-based learning. For example, while conducting the laboratory work of physical free fall acceleration setting, the answer to the problem of

the study can be found in the literature (it is known that gravitational acceleration equals to $9,81 \text{ m/s}^2$). Received information in the first cycle of the research is the starting point for the studies, which are done later on. In this case, the recognition, that accumulated information can be combined with an original idea, experiment and/or an opportunity to provide new information, holds a huge significance (ACRL, 2000).

The second case of the search of information in inquiry-based learning is more complicated. It reveals two cycles: analytic cycle with literature; analytic cycle with empiric data (Figure 3). Thus, a student cannot find an answer to the questions during the first cycle (analytic cycle with literature) in experimental activity, since there is no source that defines the purpose of the research. The answer is revealed only by experimental activities (analytic cycle with empirical data). Research which is done according to the second model Exner (2014) defined as authentic research and people, who are investigating it - authentic researchers (Exner, 2014). It can be assumed that authentic researchers, while gathering information, have to know types of information sources (primary, scientific, etc.), formats and other parameters. Covered topics have to be well-reviewed, other than that authentic researchers have to be disciplined enough to use appropriate sources for the study. On the other hand, authentic researchers should be able to find the necessary information during an experiment and be able to discover the needed information from the survey data (Fig. 3).

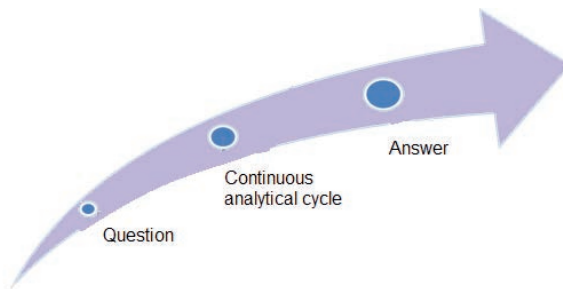


Fig. 2. Information retrieval method based on the analysis according to ACRL (2000)

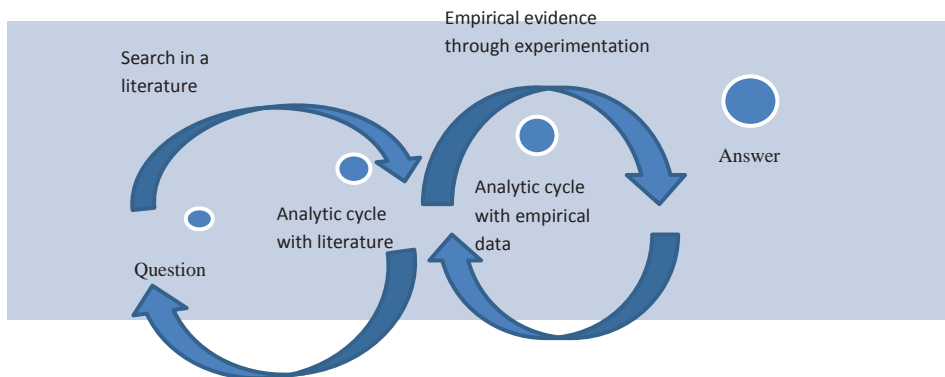


Fig. 3. Information retrieval character in experimental activity in accordance with Exner (2014)

Getting deeper into inquiry-based learning theoretical insights (Bell, 2005, 2008; Exner, 2014) the relationship between inquiry-based learning levels (Bell, 2005, 2008) and inquiry-based learning cycles model (Exner, 2014) can be seen. Conducting the experiments according to the first level of inquiry-based learning, students' information search is limited to a single cycle (Fig. 2). Students only have to experimentally verify presented information in the means of learning. Thus, it can be said that the first level of IBL is associated with a single cycle of the search of information model.

Conducting experiments based on 2nd–4th level methodologies (Table 2) revealed the learners role as an authentic scientist. A new cycle of information retrieval appears and work with empirical data is being done, after two cycles response is formulated (Fig. 3). Authentic researchers role particularly reveals itself in an open IBL level (Table 3).

Table 3

Exploration levels according to Bell (2008) and cycles in accordance with Exner (2014)

Exploration level	Question	The progress of the investigation	Expected result	IBL and the cycles of information retrieval
1 level confirmatory research	Known	Known	Known	Model of one cycle of information retrieval. Research data derives from the sources of information.
2 level structurized research	Known	Known	Unknown	
3 level coordinated research	Known	Unknown	Unknown	Model of two cycles of information retrieval. Research data derives from the process of research.
4 level open research	Unknown	Unknown	Unknown	

Discussion

The conducted analysis revealed that inquiry role in the learning process and the concept of “inquiry-based learning” researchers comprehend and interpret it quite differently. It can be explained by a long and complicated history of inquiry in the learning process. Inquiry-based learning roots can be found in the teachers, who played an active role in researching children’s learning patterns, works, which include even J. J. Rousseau (1712–1778) and J. Pestalozzi (1746–1827). The term “inquiry” got interested scientists later on, they tried to describe and justify it. However, an abundance of descriptions of inquiry-based learning found in the literature shows that attempts to define this methodology are still going on. It is hard to find the first appearance of the term “inquiry provisions” although it can be said that inquiry provisions have old dialogue origins about learning and teaching, which were hugely influenced by J. Piaget (1896–1980), L. Vygotsky (1896–1934) and D. Ausubel (1918–2008) works.

The statements can be found that these theorists’ works have been integrated into the constructivist learning philosophy (Cakir, 2008), in the developed form is known as social constructivism (Mayer, 2004), which was used to form inquiry-based teaching and learning theoretical basis and generally to get anew grasp of the learning process.

Notwithstanding the fact that inquiry-based learning does not have precise definition, the basic elements are clear and scientists essentially agree on them. It is important in this study.

Inquiry-based learning rests on four principles, which are common to all of the modern theories of learning: learning takes place through constructive, science based, knowledge structures; transfer of knowledge is focused on the process, which combines conscious and unconscious perception; the circumstances, when knowledge is acquired and subsequently used, have to be set at the beginning of the study period; knowledge is constructed so as to be reliable and sustainable currently and also could be applied in the distant future.

Inquiry-based learning program consists of three stages: motivation, knowledge construction and its’ improvement. This means that in anticipation of the success in the learning process, in the studying context it is important to use the right motivational measures for the learners and route them via the skills or knowledge, which they reasonably apply. The success of knowledge construction stage depends on the new knowledge structure in the memory. Learners construct the new knowledge as a continuation the current practice in order to add them to the new concepts constructive and to divide existing concepts or develop a new connection between the concepts. The material, which their new knowledge is constructed from can be personal experience, gained knowledge while interacting or personal experience and gained knowledge mixture. Activities that provide the learners an opportunity to retrospectively reflect their knowledge and experience allows to update available information, creates preconditions for development.

Learners see an opportunity to apply their knowledge in a meaningful way and it helps to understand that it is needed, i.e. it gives a meaning to them and motivates to learn.

Rissing and Cogan (2009) confirms it, they determined that inquiry method allows to link classroom activities with personal experience and that is why students are more motivated to learn, (Gormally et al., 2009) and Gibson (1998) findings state that teaching programs which rest on inquiry-based learning help students to maintain interest in learning and motivates them.

Large-scaled studies have shown that inquiry-based learning is more effective than traditional learning methods (for example Linn et al., 2006). Thus, inquiry-based learning experience can provide students with very important development opportunities, that is the understanding the nature of science and scientific experience, but the appliance of inquiry-based learning in education, according to Edelson and other scientists (1999), still has a few difficulties.

Nevertheless, inquiry-based learning has been listed as the methodology that promotes students' interest and higher learning achievements (Rocard et al., 2007). In addition, it was admitted, that inquiry-based learning methodology is appealing in addressing the challenges of learning (Rocard et al., 2007). The debatable question is on the teachers, who are prepared to work with application of inquiry-based learning, training, preparation of the appropriate tasks for the methodology, concepts compatibility requires new research.

Conclusions

1. Inquiry-based learning is a learning methodology based on constructivism. According to IBL, a vital points in the learning process are learners initial level of knowledge, attention to the self-learning process and an appropriate learning content. IBL origins lie in classic pedagogy. The rudiments of this methodology can be found in J. Rousseau (1712–1778), J. Pestalozzi (1746–1827), H. Lane (1875–1925), J. Dewey (1859–1952), M. Montessori (1870–1952) and the works of other researchers. These teachers emphasized students' curiosity, imagination role and desire to interact. In the modern science of education IBL is perceived as a learner-centered studying, when critical thinking, problem solving and interacting skills are of a more importance than just basic presentation of knowledge.

2. IBL methodology in an experimental practice of natural sciences can be realized by using 5E model: engage, explore, explain, elaborate, evaluate. In accordance with this model students acquire new knowledge gradually, on the basis of critical thinking and problem solving.

3. An appliance of 5E model in experimental activity is grounded by the level of research. 4 levels of IBL are distinguished: confirmatory research, structured research, coordinated research, open research. IBL levels of the research are based on the complex-

ity of experimental activity. The least complex - first level, when the learner is presented with the problem of a research, its path of solution, beforehand known response. The most complex – fourth – level of an open research. At this level student him self has to discover the problem of a research, predict the path of solution, discover beforehand an unknown answer. In the first level the most important step - explore, in the fourth level – explain and elaborate.

4. IBL levels determine the search of information in experimental activity of natural sciences. In the first level an information can be found antecedently in the literature (one cycle of the search of information), in the fourth level – information derives from research data (two cycles of the search of information). Thus, in the fourth level a role of authentic researchers is particularly conceded.

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Teorinės tyrinėjimais grindžiamo mokymosi gamtamoksliniame ugdyme įžvalgos: nuo ištakų iki 5E modelio

Džeraldas Dagys

Lietuvos edukologijos universitetas, Ugdymo mokslų fakultetas, Edukologijos katedra, Studentų g. 39, 08106 Vilnius, dzeraldas.dagys@gmail.com

Santrauka

Straipsnyje pateikiamos teoriniais tyrinėjimais grindžiamo mokymosi (toliau – TGM) metodologijos gamtamoksliniame ugdyme įžvalgos. Ieškoma atsakymo į klausimus, kada atsirado tyrinėjimais grindžiamas mokymasis, iš kokios ugdymo filosofijos kildinama ši mokymosi metodologija. Nagrinėjama, kokiais principais remiasi tyrinėjimais grindžiamas mokymasis. Apžvelgiami TGM modeliai, pateikiama informacija apie tyrinėjimo lygmenis. Atskleidžiami tyrinėjimais grindžiamo mokymosi pranašumai.

Atliekant tyrimą, nustatyta, kad:

1. Tyrinėjimu grindžiamas mokymasis yra indukcinė mokymosi strategija, kuri leidžia mokiniams patiems kurti ir kaupti žinias apie mokymosi procesą, plėtoti mąstymo įgūdžius ir didinti susidomėjimą bei mokymosi motyvaciją, kuri grindžiama technologijoms imlia mokymosi aplinka. Tyrimais pagrįsta eksperimentinė veikla gamtamokslinio ugdymo kontekste yra labai svarbus formuojantis elementas mokinio mokymosi procese.

2. Tyrinėjimu grindžiamas mokymasis efektyvesnis už tradicinius mokymosi būdus. Tyrinėjimu grindžiamo mokymosi patirtis gali suteikti mokiniams labai svarbias tobulėjimo galimybes, t. y. mokslo esmės suvokimą ir mokslinę patirtį. Tai įrodė didelės apimties tyrimai (pavyzdžiui, Linn et al., 2006).

3. Taikant tyrinėjimu grindžiamą mokymąsi, vyksta dvigubas informacijos vertinimas, kuris daro pozityvią įtaką mokinių gebėjimui atrinkti informaciją, ją tvarkyti ir vertinti. Tyrimo metu eksperimentinis procesas buvo nagrinėjamas ne kaip įprastas informacijos paieškos (radimo) ciklas, kai žinant klausimą ieškoma atsakymo atliekant literatūros analizę, tačiau kaip sudėtingesnis procesas – kai atsiranda naujas ciklas ir dirbama su empiriniais duomenimis ir tik tuomet, po dviejų ciklų, formuluojamas atsakymas. Tai įrodė Kolegijų ir mokslinių bibliotekų asociacijos (angl. *Association of College and Research Libraries (ACRL)*) atlikti tyrimai.

Esminiai žodžiai: *tyrinėjimu grindžiamas mokymasis, TGM modeliai, tyrinėjimo lygmenys.*

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