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KNOWLEDGE RETENTION IN SHORT AND SEMESTER-LONG COURSES IN SKOLKOVO BACHELOR OF BUSINESS ADMINISTRATION PROGRAM / УДЕРЖАНИЕ ЗНАНИЙ НА КОРОТКИХ И СЕМЕСТРОВЫХ КУРСАХ В РАМКАХ ПРОГРАММЫ БИЗНЕС-БАКАЛАВРИАТА СКОЛКОВО И МФТИ

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МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
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ВЫПУСКНАЯ КВАЛИФИКАЦИОННАЯ РАБОТА
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KNOWLEDGE RETENTION IN SHORT AND SEMESTER-LONG COURSES IN SKOLKOVO BACHELOR OF BUSINESS ADMINISTRATION PROGRAM / УДЕРЖАНИЕ ЗНАНИЙ НА КОРОТКИХ И СЕМЕСТРОВЫХ КУРСАХ В РАМКАХ ПРОГРАММЫ БИЗНЕС-БАКАЛАВРИАТА СКОЛКОВО И МФТИ

44.04.01 Педагогическое образование:
Магистерская программа «Экспериментальное высшее образование»

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INTRODUCTION

Universities, as educational institutions, create a specific learning environment that emerged in ancient times and had its own form of evolution. Therefore, the educational environment of universities relies strongly on academic traditions and is quite resistant to rapid changes. However, these changes are unavoidable processes of today's world. Not only does the demand of the industry become higher, but students' demand for high-quality education also rises. According to the World Bank, "globally, in 2021, roughly 220 million students were enrolled in formal post-secondary education, more than doubling the enrollment figure from 2000. It is estimated that there will be 380 million higher education students by 2030" [Murthi M., Bassett M. R., 2022[1]]. Considering the students' demand and understanding what they value in higher education is crucial for higher education institutions around the world. According to global surveys, students not only value skills that lead to meaningful work, but also those that lead to a meaningful life. They prioritize connections and opportunities that provide security and purpose in their lives [Murthi M., Bassett M. R., 2022[1]]. In order to prepare students for the fast-changing realities of today's labor market, universities should adapt their educational models and learning process in a way that ensures real knowledge acquisition and retention. Knowledge retention is a multidimensional process that different factors can influence. Therefore, universities should consider different approaches to organization of the learning process, starting from increasing students' engagement and ending with specific course formats and organization, to provide students with the most effective learning experience and knowledge acquisition. Suppose a university has a well-developed tool for studying knowledge retention. In that case, it will have data to introduce evidence-based changes to the educational process that will raise its efficiency. Therefore, the relevance of this work is predetermined by the need for universities to enhance the learning process and create an educational environment that will ensure knowledge acquisition, its further retention and usage in specific working or live situations.

[1] URL: https://blogs.worldbank.org/education/higher-education-understanding-demand-and-redefining-values

Higher education institutions are already introducing new technologies (virtual reality, augmented reality, simulations, etc.), as well as new approaches for organization of the educational process (problem-based learning, action learning, gamification, etc.) that might potentially increase knowledge retention. In the framework of this study, the case course organization in Bachelor of Business Administration, a joint program of SKOLKOVO School of Management and Moscow Institute of Physics and Technology (SKOLKOVO-MIPT BBA program), will be analyzed. Therefore, the **object** of this research is a joint program of SKOLKOVO School of Management and Moscow Institute of Physics and Technology Bachelor of Business Administration, the **subject** of the research is knowledge retention in short and semester-long courses.

The study's main goal will be to study knowledge retention in short and semester-long courses of the program. In order to fulfill this goal, this research has the following **objectives**:

1. To analyze the concept and the notion of knowledge retention.
2. To connect knowledge retention to fundamental theories of learning and memory.
3. To describe tools that are being used to study knowledge retention or foster it.
4. To describe the institutional context of SKOLKOVO School of Management and Moscow Institute of Physics and Technology, give a description of the Bachelor of Business Administration Program.
5. To describe a research design and methodological framework of the thesis study.
6. To interpret the result of the research and outline the field of further discussion

In order to fulfill these objectives, a literature review was conducted. This research is based on several **types of sources**:

- Fundamental theories of learning and memory, e.g., Anderson & Krathwohl (2001), Ebbinghaus (2013), Letrud (2012), Turesky & Wood (2010).
- Practical implications of knowledge retention studies, e.g., Beers & Bowden (2005), Chittaro & Buttussi (2015), Cloke (2021), Frankart, Patterson, Crawford, Donohoe, Gatewood & Goode (2022), Ibrahim Al-Shara (2007), Levin-Banchik

(2018), Lindsey, Shroyer, Pashler & Mozer (2014), Seamon (2004), Tennyson & Beck, (2018).

- Internal and organizational documents of SKOLKOVO-MIPT Bachelor of Business Administration program.

The main **research question** of this thesis is how course organization in the SKOLKOVO-MIPT BBA program influences knowledge retention. In order to answer this question, knowledge tests were used. The research also included a qualitative part that consists of short structured interviews with each student. The interview included questions related to the motivation of students to learn, their engagement in classes, educational expectations and challenges. Students received individual knowledge tests, which will include disciplines from SKOLKOVO and MIPT modules that they have finished in the previous semester. Students will solve these tests; the answers will be analyzed with the help of descriptive statistics, and compared with the results from the previous semester. On the one hand, the findings of the research will contribute to the global discussion of knowledge retention studies in academic context. On the other hand, it will provide data on the current efficiency of the educational process and recommendations for the possible adjustments to enhance the learning experience of students.

In the **first chapter** of the thesis, a literature review is presented. The literature review is divided in three parts:

- fundamental theories of learning and memory, which play a significant role in knowledge retention and the derived dimensions of knowledge retention;
- a review of the relevant studies of knowledge retention: their foci, goals, and connection to the dimensions of knowledge retention,
- a review of the existing tools to study knowledge retention in academic and non-academic contexts.

The **second chapter** of the thesis provides a description of the study and methodological framework. In this chapter, an institutional context of the program is given. Research design with theoretical underpinnings, as well as the description of the

choice of material and the structure of the study, is given. The description of the specific analysis aspects, as well as the results' interpretation, is conducted.

In conclusion, the direction for further discussion is outlined.

CHAPTER 1. THE CONCEPT OF KNOWLEDGE RETENTION AND APPROACHES FOR STUDYING IT

1.1. THE CONCEPT AND NOTION OF KNOWLEDGE RETENTION

Today, in the context of information overload, it is only natural that people tend to forget things that are not relevant to their current occupation or life. Forgetting is a natural process that occurs in our everyday life and the learning process. However, in the educational context, it is crucial that learners retain as much knowledge as possible in order to fulfill their career goals or goals of personal development. Therefore, the role of the education system, in general, can be defined as the organization of the educational process in a way that supports acquired knowledge, and serves for its retention and further applicability.

Knowledge retention can be defined as both the domain of studies and the process. As the domain of studies, it is possible to describe knowledge retention as the methodological framework to study students' ability to remember information from his previous educational experience. As the process, according to Helen Colman, learning, memory and retention are closely intertwined concepts, where learning stands for knowledge acquisition, memory–for its storage, and retention–for storing information in a long-term memory, so it could be used in the future [Colman H., 2022[2]]. Thus, it is possible to say that knowledge retention is one of the most important aspects of studying the efficiency of the learning process.

Talking about aspects of knowledge retention and its elements, it is significant to mention that in the context of the learning process students are exposed to different factors, which can affect knowledge acquisition. These factors can be internal (students' motivation to study and applicability of knowledge, individual learning capacities) or external (teaching method activity, course length and intensity, time after course completion, the novelty of the material). Thus, talking about knowledge retention, we should also consider the specific learning environment in which students are put.

[2] URL: https://www.ispringsolutions.com/blog/learning-retention

Knowledge retention is an important part of studying the learning process, which can provide scientific data on the efficiency of the educational model. However, since the learning process can be specific for each student and can be influenced by the specific learning environment, it is necessary to develop a framework, which will consider these aspects and will provide relevant, non-biased data on the educational process. In order to do that, it is essential to address fundamental learning theories, which will serve as a base for developing a methodological framework.

1.2. CONNECTION OF KNOWLEDGE RETENTION TO FUNDAMENTAL THEORIES OF LEARNING AND MEMORY

Knowledge retention is deeply intertwined with the process of learning itself, therefore it is possible to draw a connecting line between the concept of knowledge retention and some fundamental theories of learning and memory, which will at the same time provide important dimensions for studying knowledge retention.

Since retention of knowledge presupposes the ability to retrieve knowledge from long-term memory and apply it to specific situations, it is possible to look at this concept through the Experiential Learning Theory. According to this theory, a student goes through the cycle of concrete experience (feeling), reflective observation (observing), abstract conceptualization (thinking) and active experimentation (doing) [Turesky E., Wood D., p. 3]. A study, conducted by Laura M. Frankart, Julie A. Patterson, Alexis N. Crawford, Krista L. Donohoe , Sharon S. Gatewood and Jean-Venable R. Goode supports the idea of greater knowledge retention if acquired information can be applied in future situations. In this study, different formats of immunization courses (one-day co-curricular seminar or five-week required course) were tested in terms of knowledge retention. The study showed that the course format did not play a significant role in knowledge retention, however students, who were able to apply this knowledge, had a higher rate of knowledge retention [Retention of students' knowledge of immunizations following a one-day or a five-week course, p. 1104-1108]. Thus, it is possible to say that students retain knowledge better if it is supported with specific experience of its application. In this sense, it is possible to say

that Experiential Learning Theory reveals one of the dimensions of knowledge retention, which is applicability of knowledge.

Another fundamental concept that is deeply interconnected with knowledge retention is the Forgetting Curve, developed by Hermann Ebbinghaus [Ebbinghaus H., p. 155]. Ebbinghaus described with this model how people exponentially forget information over time and the main factors that lead to the memory loss, i.e., individual strength of memory, the time-period since the information was learned. However, in this part, it is also important to mention that some learning platforms are developing ways to overcome the exponential information loss with the help of micro-learning technologies that help to minimize the loss of information over time [Cloke H., 2018[3]]. The before-mentioned aspects of memory functioning open other dimensions of knowledge retention, which are individual learning capacities and the time after course completion. Relating to this dimension, it is also significant to pinpoint such aspects as the course length and its intensity. For example, Mark Seamon in his study stated, "intensive courses, because of their superiority in cultivating higher order learning, would produce deeper, longer-lasting memory and recall of information than semester-length courses" [Seamon M., p. 865]. Thus, another aspect that influences knowledge retention is the mode of learning and specifically the length of the course, since it may demand more effort from students to engage and acquire knowledge and consequently influence the process of its internalization.

Another fundamental aspect that is connected to the knowledge retention is the learning environment that either fosters or suppresses students' engagement in the learning process. The level of students' engagement in the learning process also determines their motivation to learn, which has a significant influence on the knowledge acquisition. The learning environment and course instructor may be the main facilitators of students' engagement and motivation to learn through specific learning activities, which presuppose active learning. In this sense, it is important to address the Learning Pyramid, which was developed by the National Training

[3] URL: https://elearningindustry.com/forgetting-curve-combat

Laboratory. According to this concept, the percentage of retained knowledge is deeply interconnected with teaching activity and class format: the more interactive the format, the more knowledge students retain [Letrud K., p. 117]. Even though this model received a sufficient amount of critique due to the lack of the empirical evidence for specific percentage of the retained knowledge, still, active learning and interaction with knowledge helps students to retain it better, if we look at this process from the point of view of Experiential Learning Theory. Thus, it is possible to say that teaching activities or students' motivation to learn is another dimension of knowledge retention.

Talking about students' engagement in the learning process and active interaction with knowledge, it is also important to consider different levels of knowledge and cognitive processes. In this sense, it is possible to connect knowledge retention to the Revised Bloom's Taxonomy [Anderson L. W., Krathwohl D. R., p. 25]. This taxonomy introduces different cognitive and knowledge dimensions that are related to different levels of learning and presupposes different levels of effort that students should put in order to learn the information. It is possible to highlight two fundamental concepts of the taxonomy: cognitive dimensions and knowledge dimensions. The cognitive dimensions include specific cognitive activities that build on one another in their complexity. They include such activities as remembering, understanding, applying, analyzing, evaluating, and creating. Thus, in order to apply knowledge, a student should firstly remember and understand this knowledge. Another domain is knowledge dimensions, which include such aspects as factual knowledge (the basic knowledge that students should know within a discipline), conceptual knowledge (the relations of the basics concepts and knowledge), procedural knowledge (how to apply the knowledge in order to solve a task), and meta-cognitive knowledge (knowledge of cognition in general) [Anderson L. W., Krathwohl D. R., p.29]. These knowledge dimensions present different levels of knowledge, which also presuppose different levels of students' engagement with their own knowledge. For example, it will take more effort for a student to solve a mathematical equation (procedural knowledge), than simply remember the formula (knowledge dimension). Suppose, the more effort students put in learning activities, the higher the level of knowledge

retention, since the engagement with knowledge is also deeper. This, consequently, reveals another dimension of knowledge retention – cognitive and knowledge dimension of learning.

Drawing from the aforementioned fundamental theories of memory and learning, it is possible to derive the following dimensions of knowledge retention: applicability of knowledge, individual learning capacities, the time after course completion, the length of the course, teaching activities and student's motivation, cognitive and knowledge dimensions of learning (Figure 1). These dimensions are simultaneously the main factors which may influence knowledge retention and serve as a theoretical framework for studying knowledge retention.

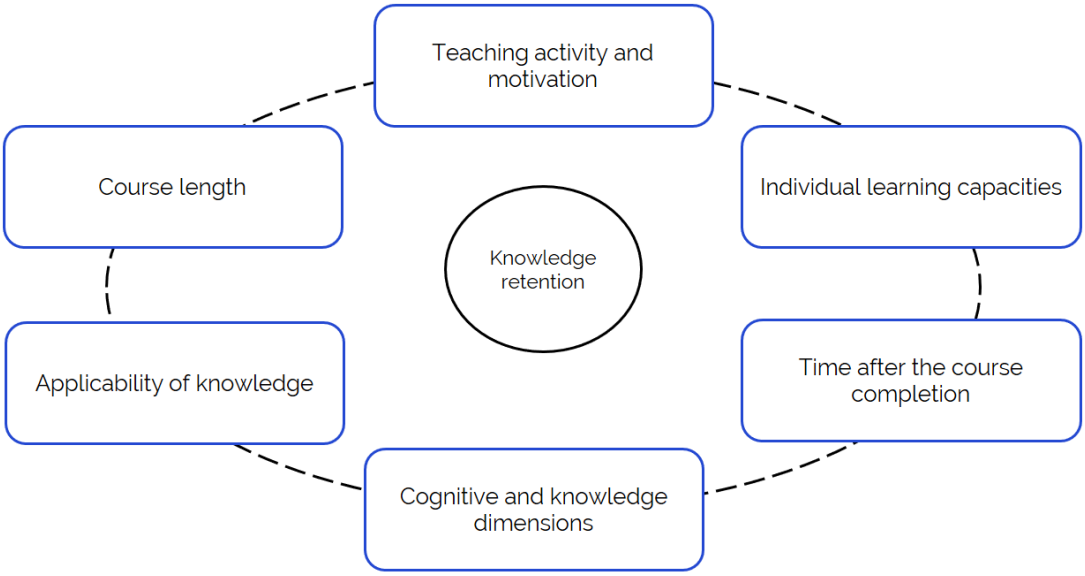

Fig 1. The dimensions of knowledge retention

However, talking about the retention of knowledge, it is also important to consider the specific educational context in which learning occurs and what specific elements of the educational environment can influence the process of knowledge retention. Therefore, it is essential to study the existing approaches for measuring or studying knowledge retention in different educational environments in order to reconstruct different approaches to this process and representation of the derived dimensions of knowledge retention in these studies.

1.3 APPROACHES AND PRACTICAL NEEDS FOR STUDYING KNOWLEDGE RETENTION IN HIGHER EDUCATION

Approaches for studying knowledge retention may differ according to the specific educational environment. They may focus on a specific teaching method or specific learning technology. The general aim of these approaches is to ensure the efficiency of the existing educational model (including teaching method, organization of courses, etc.) or to study educational outcomes of experimental modes of learning (e.g., the use of immersive technologies) in terms of knowledge retention. Therefore, talking about practical implications of knowledge retention, it is important to consider the aim of the study (to test the efficiency of new technology or provide analytical data on the existing one) and specific educational context (class format, teaching method, in-class activities, etc.).

As an example of knowledge retention study, conducted in order to provide analytical data on specific class format, it is possible to mention the study of Gerri W. Beers and Susan Bowden [Beers G. W., Bowden S., p. 511-514]. In this study, the authors measured knowledge retention in two medical courses, one of which was conducted in problem-based learning (PBL) format and another in traditional lectures. This study includes such dimensions of knowledge retention as time after course completion (since it was conducted two times: right after course completion and after some period of time) and teaching activity (since the variables specifically included traditional lecture format and PBL class).

Another example of knowledge retention study is connected to the testing of the new technology that serves to foster knowledge retention. The study, conducted by Robert V. Lindsey, Jeff D. Shroyer, Harold Pashler and Michael C. Mozer, aimed at the introduction of systematic personalized review that combined statistical techniques for inferring individual differences with a psychological theory of memory. The proposed method of personalized review is a technology of information revision that was integrated in a semester-long foreign language course. It selected material based on the individual’s learning history and performance, helping students to effectively

review material at their own pace and enhance knowledge retention [Improving students' long-term knowledge retention through personalized review, p. 639-647]. It is possible to observe how this study connects to the dimension of individual learning capacities of knowledge retention, since students were able to review information based on their general performance and, therefore, remember a bigger amount of material. Another example of this type of knowledge retention research is the study, conducted by Luba Levin-Banchik. It was aimed at testing the value of simulations and post-simulation debriefing for long-term knowledge gain, as well as emphasizing the usefulness of pop quizzes as an assessment tool. This study focuses on the format of simulation as a tool to foster knowledge retention and students' engagement in their learning using different instructional methods [Levin-Banchik L., p. 341-359]. Since simulation as a method of teaching presupposes an active interaction and engagement of students in the educational process, it is possible to say that the framework of this particular study touches upon not only teaching activity, but also students' motivation to study. Another study, which can be attributed to the introduction of new technologies in order to enhance knowledge retention, is the study, conducted by Luca Chittaro and Fabio Buttussi. In this study, the authors introduced immersive technologies as a tool for Aviation Safety teaching. One of the most important parts of the study, that authors highlighted, is that the test of knowledge was conducted several times after course completion in order to observe the process of retention of vitally important knowledge, which will be applied in the case of the aircraft accident [Chittaro L., Buttussi F., p. 529-538]. Talking about time-spans between knowledge acquisition, it is possible to mention a study, conducted by Matthew F. Tennyson and Marc Beck. In this study, the authors explore knowledge retention of students across introductory programming courses. The study showed that the students that took a longer hiatus between courses had a significantly lower level of knowledge retention [Tennyson M. F., Beck M., p. 13-20]. Therefore, it is possible to conclude that these studies address such dimensions of knowledge retention as time after course completion, teaching activity and applicability of knowledge. A similar study was conducted by Mohamed Ibrahim and Osama Al-Shara. In this study, the authors introduced a combined virtual reality and

interactive teaching technique as a tool to increase students' engagement and motivation to learn. The authors strongly emphasize the necessity to adapt and transform traditional teaching methods to the new educational context, where it is critical to provide students with an interactive learning experience [Ibrahim M., Al-Shara O., p. 347]. Thus, it is possible to say that this study focuses on such dimensions of knowledge retention as teaching method and motivation of students to learn.

From this literature review, it is possible to see how different studies address different dimensions of knowledge retention. However, they mainly focus on one or two dimensions of knowledge retention, consequently ignoring other aspects, which influence this process. Thus, it is possible to say that the studies on knowledge retention are being conducted in thematic clusters, which focuses on individual aspects of knowledge retention, leaving other aspects without attention. As it can be observed from the conducted literature review, the studies mostly touch upon the dimensions of teaching activity and motivation, time after course completion, applicability of knowledge and individual learning capacities, while dimensions of course length and cognitive and knowledge dimensions are on the periphery of the researchers' attention. This fact can be supported by different practical needs for studying knowledge retention, which puts some dimensions in the center of studies.

Synthesizing the goals for studying knowledge retention from the reviewed sources, it is possible to highlight the following needs for studying knowledge retention:

- to provide a statistical data on the efficiency of the specific teaching activity or class format;
- to provide a data on the efficiency of different assessment tools and modes of assessment to foster knowledge retention;
- to provide a justification, new technologies' integration in the educational process.
- to provide data on the efficiency of the current educational model.

These practical needs for conducting knowledge retention studies are the main factors which predetermine which dimension of knowledge retention should be

included in the study. However, it is important to consider that knowledge retention can be influenced by different factors, which are important to consider in order to get the pure data on the actual level of knowledge retention and use it further to ensure the efficiency of the existing or experimental educational model or modes of learning. Talking about studying or measuring knowledge retention, it is also important to consider specific tools for such studies which will help to address as many factors which influence knowledge retention as possible and will help to reach the initial goal of knowledge retention study.

1.4. TOOLS THAT ARE BEING USED TO STUDY KNOWLEDGE RETENTION OR FOSTER IT

Knowledge retention is deeply intertwined with assessment processes, since it presupposes information retrieval from long-term memory to apply to the specific learning or life situation. In this sense, it is important to define what the assessment process is and how it can be applied to knowledge retention studies.

Academic philosopher Michael Scriven introduced in 1967 the notions of formative and summative assessment, emphasizing the different goals in the process of evaluation [Scriven M., p. 39-37]. Summative assessment is a periodical assessment which is conducted in order to understand what knowledge and skills students have at a specific time period, and usually include such types of activities as state exams, district benchmark or interim assessments, end-of-unit or chapter tests, end-of-term or semester exams, scores that are used for accountability for schools (AYP) and students (report card grades) [Garrison C., Ehringhaus M., p. 1]. Even though this type of assessment provides the information on the acquired knowledge, some aspects of learning are left out of the focus. This type of assessment is often used to provide information about the effectiveness of educational programs in general, and does not provide information on the learning process, which occurs in the class.

In order to provide this type of evaluation, formative assessment is being used. Formative assessment is a part of the instructional process, typically used to provide information to adjust teaching and learning while they are happening [Garrison C.,

Ehringhaus M., p. 1]. This type of assessment is carried out as a practice and informs an instructor and the students about the efficiency of the learning process, in order to adjust it and help students in reaching their educational goals. The main differences of these two types of assessment is the frequency of the assessment activities (several times during the learning process or once in the end of the learning process), their goals (to ensure the effectiveness of the educational program or to ensure students reaching their educational goals) and the level of involvement of students (the recipients of the assessments or co-creators of the educational process).

It is possible to say that the process of knowledge retention studies can be considered as a part of formative and summative assessment, since it can be applied in two modes: a system of periodical knowledge revision that helps to retain knowledge or as a tool to assess overall knowledge retention after the learning process has occurred. From the literature review, conducted in the previous paragraphs, it is possible to highlight the following tools for summative assessment of knowledge retention:

- Quizzes;
- Knowledge tests:
    - related to skills that should be acquired in the learning process;
    - conducted in the end of educational process and some time after it;
    - with the use of econometric models;
- Analysis of students performance based on observations, e.g., Levin-Banchik (2018), Chittaro & Buttussi (2015), Abdulwahed & Nagy (2009); Seamon (2004), Cosgrove & Olitsky (2015), Kamuche & Ledman (2005).

However, there is also a significant amount of tools to revise information and enhance knowledge retention in the sector of corporate learning, which can be accounted as tools of formative assessment:

- Implementing reward structures to encourage sharing of key knowledge;
- After-action reviews;
- Storytelling;
- Mentoring programs, job shadowing, social learning;

- Interviews & exit interviews;
- Taking advantage of the knowledge of retirees;
- Gamification;
- Mobile and microlearning (breaking down the information in smaller blocks, providing a short learning experience at a set period of time);
- Spaced repetition;
- Active recall [Hajric E., 2018[4]; Growth Engineering company, 2018[5]; Koumadoraki A., 2022[6]].

As it is possible to see, in corporate learning there is a significantly higher amount of tools to enhance knowledge retention rate. This may be due to the necessity of knowledge management inside an organization as a mean to spread knowledge among employees, fulfill the corporate learning function and enhance the efficiency of the current processes.

However, talking about knowledge retention in the academic context, it is important to establish a methodological approach based on the following aspects:

- Connection of knowledge retention study method to the learning process and fundamental theories;
- Specific context of knowledge retention study (educational model, class-formats, etc.);
- The goal of the knowledge retention study (to provide a statistical data on the efficiency of the current model or to test the efficiency of experimental modes of learning);
- Dimensions of knowledge retention, which will be included in the study.

In the following chapter, a case of knowledge retention study will be described as an illustration of integration of these aspects in the strategy for studying knowledge retention.

[4] URL: https://www.knowledge-management-tools.net/kr.php
[5] URL: https://www.growthengineering.co.uk/5-great-knowledge-retention-tips/
[6] URL: https://www.learnworlds.com/knowledge-retention/

CHAPTER 2. FRAMEWORK FOR STUDYING KNOWLEDGE RETENTION IN THE CONTEXT OF JOINT SKOLKOVO SCHOOL OF MANAGEMENT AND MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY BACHELOR OF BUSINESS ADMINISTRATION PROGRAM

2.1. INSTITUTIONAL CONTEXT, THE DESCRIPTION OF JOINT SKOLKOVO SCHOOL OF MANAGEMENT AND MOSCOW INSTITUTE OF PHYSICS AND TECHNOLOGY BACHELOR OF BUSINESS ADMINISTRATION PROGRAM AND NEEDS FOR STUDYING KNOWLEDGE RETENTION

One of the main peculiarities of the joint SKOLVOVO School of Management and Moscow Institute of Physics and Technology Bachelor of Business Administration program (SKOLKOVO-MIPT BBA program) is that students are located in two different learning environments and contexts.

The first context is the Moscow Institute of Physics and Technology (MIPT). It is a national research university, which was established in 1946. MIPT's faculty consists of leading Russian scientists, including some Russian Academy of Sciences representatives. MIPT's mission is to train leaders in science and technology, who can solve key scientific and technical problems, and who will determine the country's and humanity's success in the XXI century [Mission & Strategy – Moscow Institute of Physics and Technology[7]]. MIPT also held several positions in the world universities rankings, e.g., in 2020, MIPT took 45th place in Times Higher Education rankings for physical sciences. Talking about MIPT's educational model, it is important to say that it has a historic value, since it was established by institutions' Nobel Prize-winners and founders Lev Landau, Pyort Kapitsa and Nikolay Semenov 70 years ago. This educational model is called the Phystech System, and it is still used by the institution. This model includes selective admission, personalized approach to teaching and involvement of scientists in the educational process. The model also combines fundamental science, engineering disciplines and student research [MIPT, 2001-

[7] URL: https://mipt.ru/english/about/mission.php

2023[8]]. Organizationally, students are being enrolled in MIPT in Phystech School of High Technology Business and considered to be a part of MIPT's educational space.

Another educational context in which students are placed is the SKOLKOVO School of Management. It is an independent non-profit institution that was established by the largest companies and famous entrepreneurs. The mission of the School is to empower the leaders of tomorrow, guiding talent to succeed in shaping the future of the country and the world [SKOLKOVO School of Management, 2023[9]]. The School is a hot spot for entrepreneurs and managers where they find new partnerships. It is the place where new business ideas are born, and where communities of like-minded people are formed and developed. Over the course of its over 15-year history, SKOLKOVO School of Management has become an important element of business relationships for dozens of thousands of people. Since the foundation of the School, it has graduated more than 50 000 students, established a 4 000 alumni community of flagship programs, and worked with 350 corporate clients. SKOLKOVO School of Management brings together the best international experience, business practices and new technologies. Corporate managers and business owners learn here from real-life cases to employ their newly acquired knowledge and skills to the best of their companies and start-ups. Research of the School's professors and experts covers international strategy, leadership, sustainable development, digital transformation, and social sector [SKOLKOVO School of Management, 2023[9]]. It has seven research centers:

- International development center;
- Leadership development center;
- Sustainable development center;
- Digital development center;
- Healthcare development center;
- Education development center;
- Public Strategy Institute.

[8] URL: https://mipt.ru/english/about/about-mipt/
[9] URL: https://portal.skolkovo.ru/SitePages/O%20школе.aspx

SKOLKOVO School of Management employs an interdisciplinary evidence-based approach to education based on research and constant search for new knowledge sources and competencies. The core faculty of SKOLKOVO School of Management works in a variety of disciplines: entrepreneurship, leadership, operating activity, project management, decision-making, negotiations, investment, innovations, HR management, finance, marketing, and communications. The School's faculty also includes visiting professors and experts from the leading international universities and business schools. The quality of the School's educational programs has been recognized on the global level: the Financial Times ranked SKOLKOVO School of Management №32 among the European business schools, listed it among the top 50 Executive MBA programs, and №1 in Europe according to the EMBA alumni salary level [SKOLKOVO School of Management, 2023[10]]. The School holds more than 80 educational programs:

- MBA programs;
- Entrepreneurship programs for the launch and development of businesses;
- Leadership and professional competencies' development programs;
- Programs for different sectors and industries;
- Solutions for the public and social sectors;
- Tailor-made corporate educational programs
- Bachelor's programs;
- Programs for young professionals;
- Programs for students of 8th-11th grades [SKOLKOVO School of Management, 2023[10]].

It is important to mention that SKOLKOVO School of Management can grant primarily non-degree (professional development) certificates, which is the reason it did not previously have bachelor's programs. However, in 2022 a joint program of SKOLKOVO School of Management and Moscow Institute of Physics and Technology (MIPT) was launched. In this partnership, students will be able to acquire

[10] URL: https://portal.skolkovo.ru/SitePages/О%20школе.aspx

educational experience in both institutions, making it more flexible and student will receive two diplomas: Management of Business Innovations bachelor's diploma from MIPT and Bachelor of Business Administration certificate from SKOLKOVO School of Management, which will ensure the quality of education both in the Russian and international business context. The structure of the program consists of three blocks:

- Natural Sciences and Technology (Mathematics, Physics, IT, Biology) is aimed at the development of the world's understanding through the lens of Natural Sciences, as well as the ability to build abstract models of real objects, work with data and solve complex problems in conditions of information deficiency.
- The block of Economics and Humanities is aimed at teaching students to work effectively with the economic, social, psychological and cultural dimensions of business, taking into account the theoretical foundations and limits of applicability of concepts and models.
- Business training (including traditional business disciplines from strategic management and entrepreneurship to marketing and finance) is aimed at giving students practical tools to implement their business ideas [О программе – Бизнес-бакалавриат СКОЛКОВО и МФТИ, 2022[11]].

The students are studying these blocks both on MIPT and SKOLKOVO School of Management campuses. During their studies, students can choose their specialization, which are:

- Business analytics;
- Sustainable development;
- Startup development [О программе – Бизнес-бакалавриат СКОЛКОВО и МФТИ, 2022[11]].

An integral part of the Bachelor's of Business Administration program is an internship in the companies of the Skolkovo ecosystem (the companies with which SKOLKOVO School of Management has a strong connection and partnership). Students have two summer internships. During the 4th year of their studies, students

[11] URL: https://www.skolkovo.ru/programmes/bachelor-of-business-administration/about-programme/

will go through a long internship, during which they will develop a project for the company. During the final internship, students can individualize their courses according to their current skill gaps by taking courses in fields and subjects in which they do not have sufficient knowledge [О программе – Бизнес-бакалавриат СКОЛКОВО и МФТИ, 2022[12]]. This way, students are allowed to study subjects essential to their effective project implementation (Figure 2).

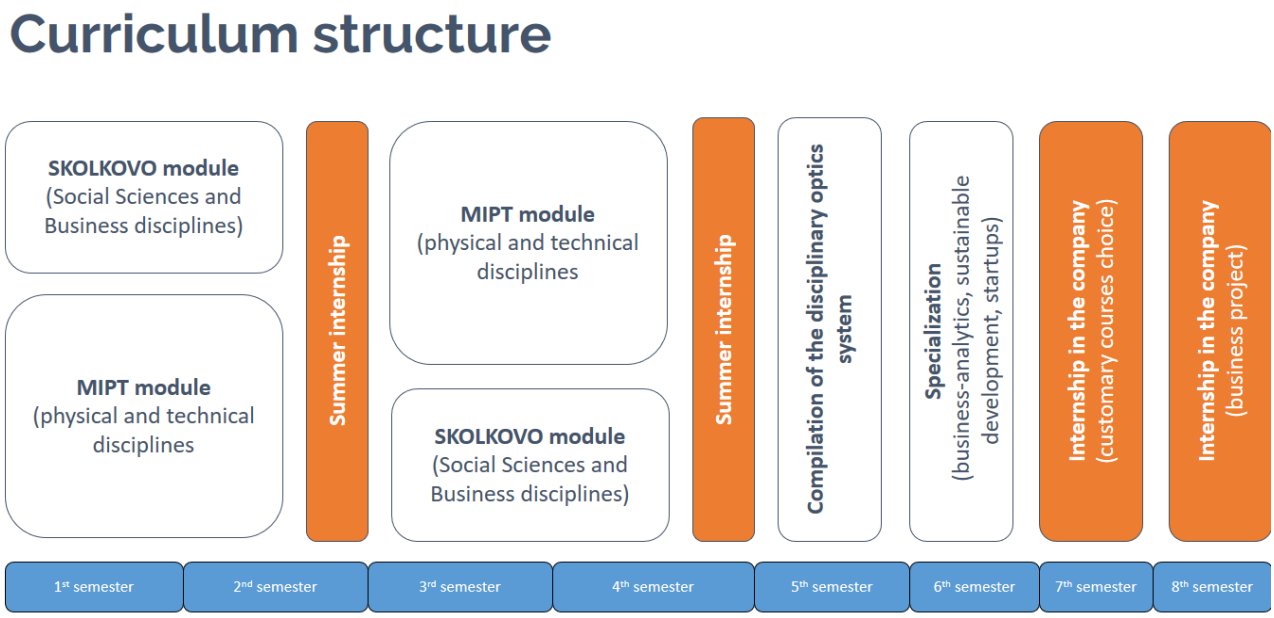

Fig 2. The structure of SKOLKOVO-MIPT Bachelor of business Administration program

An interesting part of the SKOLKOVO-MIPT BBA program is that traditional semester-long courses, conducted by MIPT, supplemented with short courses, conducted by SKOLKOVO School of Management. At the end of each SKOLKOVO module, students have an Interdisciplinary reflection, which serves to help students to establish the connections between the disciplines of the module and to learn how different approaches from different disciplines can be used to solve interdisciplinary business-cases (Figure 3).

[12] URL: https://www.skolkovo.ru/programmes/bachelor-of-business-administration/about-programme/

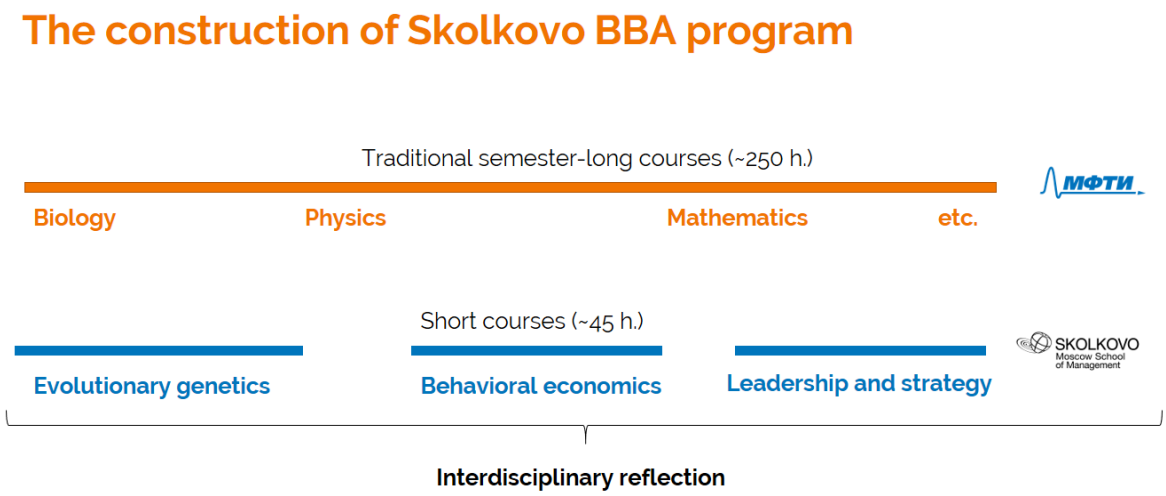

Fig 3. The construction of SKOLKOVO-MIPT BBA program

Teaching activities in SKOLKOVO courses are also significantly more flexible than the traditional semester-long courses. Considering the fact that students go through different educational experiences in the framework of the program, it is important to understand if such organization of courses positively contributes to the knowledge retention. Different duration of courses and in-class activities may play a significant role in the retention of knowledge. In this sense, it is essential to understand what type of material should be taught in the traditional semester-long format or in the format of short courses. This is the main practical need for studying knowledge retention in the program. The results of the study will help to inform the decision-making on the future organization of the courses inside the program and enhance the positive effects of students' educational experience.

2.2. METHODOLOGICAL FRAMEWORK

The fundamental design of the research is founded on the basic principles of practical implications of knowledge retention studies: testing students' knowledge at different periods and identifying the level of retained knowledge. In the case of the SKOLKOVO-MIPT BBA program, the main research problem is predetermined by the curriculum organization. The disciplines are taught in the semester-long and short formats, and it is important to ensure that students are reaching learning goals and have a positive learning experience in terms of knowledge acquisition and knowledge

retention. In order for this educational model to serve the purpose of high quality education, it is essential to provide evidence for the effectiveness of the proposed educational modes. Therefore, the main purpose of this study is to define the level of knowledge retention in short and semester-long courses, as well as define which main aspects of the program and course organization influence knowledge retention of students.

2.2.1. THEORETICAL UNDERPINNINGS

In the first chapter of the thesis, the main dimensions of knowledge retention were identified. It was concluded that due to the practical needs for studying knowledge retention, the specific dimensions are being put in the focus of the study, while other dimensions are put on the periphery. However, in order to identify the pure level of knowledge retention and factors that influence it, it is important to include in the research as many dimensions of knowledge retention as possible. Due to the diverse nature of SKOLKOVO-MIPT's BBA program, it is possible to include in the framework of studying knowledge retention such dimensions as time after course completion, course length, teaching activity and student's motivation, individual learning capacities, applicability of knowledge and cognitive and knowledge dimensions.

Since one of the peculiarities of the program is the mix of short and semester-long courses, there is consequently the need to study the efficiency of such course organization. Therefore, the educational model of the program makes the course length dimension of knowledge retention the central aspect of the study.

Semester-long MIPT courses and short SKOLKOVO courses also differ drastically in teaching activities that foster students' engagement and motivation of students to study. While SKOLKOVO courses include group work, quizzes, individual presentations and reports, MIPT courses consist primarily of the traditional lectures, seminars, and laboratory works. This distribution of in-class activities determine different levels of students' engagement in the learning process, and thus sets another dimension of knowledge retention–teaching activity and motivation–in the focus.

In the close connection to the previous dimension, the cognitive and knowledge dimension is put. If we are talking about different modes and levels of engagement in the learning process, it is important to touch upon the influence of the specific cognitive processes to the overall knowledge retention. Since different in-class activities presuppose different educational outcomes, levels of knowledge, cognitive processes, and level of engagement with knowledge, it is essential to understand how these cognitive and knowledge dimensions' influence knowledge retention in short and semester-long courses, if there is such kind of influence in the first place. Thus, the cognitive and knowledge dimension of knowledge retention is another focus of the study.

Another dimension that is significant to consider in every knowledge retention study is the time after course completion. Since SKOLKOVO and MIPT courses have different lengths and, therefore, SKOLKOVO courses pass faster, it is critical to acknowledge how the current educational model and organization of courses helps students to retain knowledge from the courses which were taken in the beginning of the semester. In this sense, if the current educational model comprehensively supports and integrates the knowledge from short courses, students will still remember some information from them even after some time has passed. Therefore, the course length dimension of knowledge retention is an important part in the analysis of the efficiency of the current educational model.

The dimension of individual learning capacities is another significant part of knowledge retention study. Usually, knowledge retention is measured by reintroducing to students the final tasks of the course after some time. However, this approach does not consider the fact that students will not be able to answer the same questions correctly, if they did not answer them correctly previously. In this sense, in order to get a pure, non-biased percentage of knowledge retention it is necessary to consider individual learning capacities of students and take an individualized approach to the development or compilation of tasks, which will be reintroduced to students.

Finally, it is important to consider the applicability of knowledge as one of the dimensions of knowledge retention. It is an essential part in every learning process,

when the student feels that the knowledge, which they are acquiring, will help them in their future professional life. In this case, the students' engagement in the educational process will be higher, as well as the level of retained knowledge. However, in this sense, it is significant to consider not only students' vision for this knowledge application, but also pay attention if they were able to apply it to their current studying or professional tasks.

The main aim and, consequently, the need for studying knowledge retention in SKOLKOVO-MIPT Bachelor of Business Administration program is to ensure the efficiency of the current educational model, which includes short and semester-long courses. In order to do so, it is critical to put in the methodological framework the main aspects that influence knowledge retention and identify factors, which influence knowledge retention in each format of the courses.

2.2.2 RESEARCH DESIGN

The main purpose of the research is to investigate the level of knowledge retention in short and semester-long courses and what may influence it. According to conducted literature review, knowledge tests conducted at different periods is one of the main tools to identify the level of the retained knowledge [Beers G. W., Bowden S., p. 511-514; Chittaro L., Buttussi F., p. 529-538; Tennyson M. F., Beck M. A., p. 13-20]. However, in order to understand which underlying factors influenced knowledge retention, it is important to use knowledge tests and combine them with qualitative research methods. Therefore, one of the main instruments of the research was individualised knowledge tests, while in the qualitative part of the research, a structured interview was conducted.

This approach for conducting research is determined by the need to cover most of the dimensions of knowledge retention. Fundamentally, the research is based on such dimensions of knowledge retention as course length. In this study, the materials from two short SKOLKOVO courses (~45 hours of in-class activities) and two semester-long MIPT courses (~270 hours of in-class activities) will be included. Talking about time after course completion, it is rather heterogeneous: students

finished MIPT courses in October 2022, while SKOLKOVO courses were finished in December 2022. Thus, the time after course completion was different at the moment of study: for SKOLKOVO courses it is 7 months, while for MIPT courses it is 4 months. This time difference, however, could not be influenced in the framework of this study, since students have a significant workload and time slots for the study are determined by the breaks between semesters, and other non-studying days.

Even though this study is fundamentally based on the length of the courses, it also covers different dimensions of the study.

Testing part of the research covers such dimensions as individual learning capacities, and cognitive and knowledge dimensions.

In order to include individual learning capacities as a dimension of knowledge retention, individualized knowledge tests were created for each 16 students, who took part in the study. In order to create these tests, an analysis of the program's courses and materials was conducted. The analysis had the following structure:

- To analyze the overall curriculum and highlight passed courses;
- To retrieve a syllabus for the courses and analyze in-class activities;
- Decide on the set of short and long-term courses that will be included in the knowledge tests (in the pool of SKOLKOVO courses they are Behavioral Economics and Evolutionary Genetics, in the pool of MIPT courses they are Introduction to Mathematical Analysis and Biology; the principles of course choice will be described in the "Materials choice" section of this paragraph).
- To get the bank of tasks (including tasks for exams and final tasks) for each course and the answers for each task.
- To obtain students' answers for these tasks and identify correct answers in each task and each course.
- To compile individual tests for each student, including only correctly answered tasks.

Each student had a set of tasks that they solved correctly previously and, therefore, the individual learning background of each student will be considered. In addition, by introducing individualized tasks to students, it will be possible to identify

a pure knowledge retention level that will not be biased by the tasks to which students initially did not know the correct answer.

When individualized tasks were compiled, it was essential to include cognitive and knowledge dimensions of knowledge retention. This element is important, since different organization of the courses and in-class activities presupposes different levels of background knowledge and students' engagement with this knowledge. For example, according to the revised Bloom's taxonomy, in order to be able to apply knowledge, students firstly need to be able to remember and understand it. In this sense, remembering, understanding and applying knowledge presupposes different levels of interaction with knowledge. Thus, it is possible to assume that on different levels of knowledge and on different levels of interaction with it, the level of knowledge retention can be different, since it presupposes different amounts of intellectual efforts. Therefore, the analysis of the chosen materials was conducted according to the revised Bloom's taxonomy (Table 1).

Table 1

Analysis of the courses and chosen tasks on the cognitive and knowledge dimensions of knowledge, according to Bloom's taxonomy

Course	Task	Knowledge dimension	Cognitive dimension
Biology	Report on lab work	Factual knowledge	Remember (List) based on Apply (Experiment)
Evolutionary Genetics	Final test	Conceptual knowledge Factual knowledge	Remember (Describe) Remember (List)
Introduction to Mathematical Analysis	Written tasks	Procedural knowledge	Apply (Calculate)
Behavioral Economics	Written tasks	Procedural knowledge Meta-cognitive knowledge Factual knowledge	Apply (Calculate) Evaluate (Conclude) Remember (Appropriate Use) Remember (List)

Since chosen tasks are primarily final tests and exam tasks and are aimed at identifying students' level of knowledge and ability to apply it at the end of the course, some tasks have correlational knowledge dimensions and cognitive dimensions (e.g., Biology and Evolutionary genetics correlate in factual knowledge, while Introduction to mathematical analysis and Behavioral economics correlate in procedural knowledge). In this sense, it is possible to analyze how different levels of knowledge are retained in different course formats and apply cognitive and knowledge dimensions of knowledge retention.

The research includes such dimensions of knowledge retention as teaching activity and motivation and knowledge applicability. These aspects of knowledge retention are analyzed by short structured interviews before individualized knowledge tests. Students will be asked questions related to such aspects as:

- To what extent educational expectations of students were fulfilled;
- What specific teaching activity helped to retain knowledge;
- What material was easier to learn and why;
- What challenges you faced in both formats of education and why;

Thus, it will be possible to see how students themselves reflect on their education, to identify the challenges they faced, as well as teaching tools that they find productive for learning and how they engaged in their learning experience.

In this sense, this study will cover most of the aspects of knowledge retention that will help to identify the specific level of knowledge retention in both formats of courses, and the specific aspects that influenced this retention.

The choice of the materials

The individualized knowledge tests were compiled based on four disciplines and tasks from them. Since the curriculum is organized in short and semester-long courses, it is important to take a set of courses of both types, but located in a similar disciplinary field, which will help to analyze knowledge retention in both formats. By conducting the analysis of the curriculum and several meetings with the administrators of the program, the following courses were chosen and divided in two blocks:

- Biology block consists of a semester-long MIPT's Biology course (270 hours of in-class activities) and short SKOLKOVO's Evolutionary Genetics course (45 hours of in-class activities);
- Mathematics block consists of semester-long MIPT's Introduction to Mathematical Analysis course (270 hours of in-class activities) and short SKOLKOVO's Evolutionary Genetics course (45 hours of in-class activities).

Since SKOLKOVO-MIPT Bachelor of Business Administration is a recently developed program and students are still at the beginning of their education, the variety of courses which can be included in the knowledge tests are limited by the courses of the first two semesters. In addition, according to the information from the program's administrators, students were primarily enrolled in the program based on the exams in Mathematics and Physics. Therefore, they had significantly less solid background in Biology, in comparison with other fields. Talking about Introduction to mathematical analysis, it is considered a more complex university-level material, which students did not encounter in school. Therefore, one of the criteria for discipline selection is determined by the novelty of the material.

Talking about the choice of tasks inside each discipline, it was mostly determined by the access to the bank of tasks and answers to these tasks. It is also important to pinpoint that the final results of knowledge retention measurement were conducted without involvement of the course instructors, therefore, each task had to have the following elements: well-formulated task description, a solution from the course instructor, and the initial answers of the students. Therefore, the analysis of the accessible materials was conducted (Table 2)

Table 2

The accessible sets of materials in each course

Course	**Type of task**	**Task description**	**Students' answers**	**Solutions**
Biology	Theoretical questions	+	–	–

Table 2 continued

	Laboratory work reports	–	+	+
Introduction to mathematical analysis	Theoretical questions	+	–	–
	Written tasks	+	+	+
Behavioral economics	Group work	–	–	–
	Individual presentations	–	–	–
	Homework	+	+	+
	Quizzes	+	+	+
	Final test	+	+	+
Evolutionary genetics	Presentations	–	–	–
	Final test	+	+	+

From the table, it is obvious that some types of tasks (e.g., theoretical questions) are excluded, because it would be impossible to identify the correct answer without course instructor involvement. For the Biology course, in the case of laboratory work, the description of the task was presented orally in the format of a lecture, therefore, it was impossible to retrieve this element. However, students described comprehensively the sequence of actions and the results of their work. Therefore, in the context of a lack of other materials, this task was used for a knowledge retention study.

In the case of Introduction to Mathematical Analysis, the written tasks for exams were used for knowledge retention study, since it has all the required elements for the research.

The choice of task for Behavioral Economics was determined by the fact that the final test was designed as a summary of the course materials and included all the elements. The same principle was used for the Evolutionary Genetics course.

After compiling a study's bank of tasks and answers, each answer sheet of each student for each discipline was analyzed in order to identify the right answers. These right answers were then transferred to individualized knowledge tests for each student.

2.2.3. STRUCTURE OF THE STUDY

The study of knowledge retention in SKOLKOVO-MIPT BBA program consists of two phases:

1. Short interview in the beginning related to the students' motivation to study and applicability of knowledge (qualitative part of the study).
2. Individualized knowledge test.

Because of the low accessibility of students and voluntary terms of conducting the study, 16 out of 24 students participated. In order to shorten the time of the overall study, be able to conduct it during the break and avoid putting additional workload on students, all participants were divided in the groups of 3 to 4 people. In a day, 2 groups were studied. At the beginning of a study, a briefing, with a description of the purpose and methods of study, was conducted. It was especially important to make it explicitly clear that the study will not influence students' academic performance or give them an evaluation of their cognitive abilities. After that, each student was interviewed individually. The set of questions was the following:

- To what extent your expectations from SKOLKOVO and MIPT courses were fulfilled?
- Which forms of in-class activities were the most productive and interesting for you?
- Which material you remembered the best and why?
- What were the challenges in the educational process?

After a short interview, a student will be provided with an individualized knowledge test. Each test has a similar structure but different set of questions:

- For Biology course, students are provided with a laboratory work description. In the description, there are materials that were used in the experiment and the description of the specific steps and processes. Students need to name a chemical reaction or the process, based on this description.
- For Evolutionary Genetics course, students are provided with a test which consists of open-ended, close-ended and multiple choice questions.
- For Introduction to Mathematical Analysis course, students have a set of equations and mathematical tasks that they need to solve.
- For Behavioral Economics course, students are provided with the tasks from the final test and some formulas and concepts that were studied during this course.

After all the answers were gathered, the tests were compared with the results which they had previously, during the initial exams in the previous semester. The interviews, that were conducted in the beginning of the study, were analyzed with the focus on the main dimensions of knowledge retention which might influence it

2.2.4. RESULTS ANALYSIS

After conducting short structured interviews and individualized knowledge tests, the results were analyzed.

The qualitative part of the research included questions which related to the students' motivation to study, influence of the teaching method activity. The analysis of the interviews will have the following structure:

- The main statements for the questions;
- Specific examples from the interviews with the code of the student.

Students had rather heterogeneous answers for the question "to what extent educational expectations of students were fulfilled". For education in MIPT students had well-developed expectations. Most of the students stated that they expected the education in a traditional technical university to be challenging, and they were ready for these challenges.

"We heard a lot about education in MIPT, so in general, expectations corresponded to reality" (S2-15).

However, talking about educational expectations in the disciplines in SKOLKOVO School of Management, there was a proportion of students who did not know what to expect, and their educational expectations formed during the education.

"There were no clearly defined expectations from the SKOLKOVO courses as such; we learned about them directly in SKOLKOVO" (S9, S6, S2, S16).

Also, it is important to mention that some students stated that the education in SKOLKOVO was not fundamental. Due to the week-format of courses students had an opportunity to touch upon the discipline, to get the basic understanding of the main concepts, but they were not able to get deeper in the disciplines and the deeper understanding of knowledge in the framework of these disciplines were not developed. Also, some students stated that some SKOLKOVO courses were not sequential, for example, during the Evolutionary Genetics course students studied neurobiology, while this domain requires a more fundamental knowledge in Biology. Therefore, students faced some challenges during their education.

"There were expectations from SKOLKOVO courses that they will be not traditional, but not fundamental either, because it is impossible to immerse in a subject in a week" (S4, S8).

Students also had different modes of engagement with the learning process during SKOLKOVO and MIPT courses. Students stated that during SKOLKOVO courses, the course instructors engaged students in the learning process through interactive formats of learning. Therefore, motivation for studying was higher. In MIPT courses students' motivation to engage with knowledge was mostly predetermined by the necessity to pass the exams. They actively engaged with knowledge during the preparation for exams, when they had to revise and remember all the material which they studied during the MIPT courses. Overall, educational expectations of the majority of students were fulfilled both for MIPT and SKOLKOVO courses.

"I liked the disciplines in which there was a non-standard approach to teaching" (S11).

"In SKOLKOVO courses, the course instructors were able to engage us and make the education interesting; at the MIPT, many subjects did not seem interesting simply because many instructors did not try to engage us somehow" (S15).

Relating to the statement of the necessity of students' engagement in education in order to raise their motivation to study, let's look at the answers to the question "which forms of in-class activities were the most productive and interesting for you". For SKOLKOVO courses, all the students highlighted the interactive formats of learning and specifically the group works . All students stated that this format is crucially important to them since they had an opportunity to try different roles in the groups, including the role of the group leader. They see it as an important factor for leadership development, since they see entrepreneurs as individuals who are able to accumulate and coordinate people around them and, therefore, they see it as an important part of business education.

"In SKOLKOVO, we worked in teams every day, there were interactive classes. This shaped my thinking a little differently, I saw how you can teach, how you can learn in a different way, and I will most likely use this in my life" (S5).

"In SKOLKOVO we had a space and opportunity to develop communication skills, to prove ourselves as leaders and team members" (S8).

"It is interesting to do group projects, you can show leadership qualities, help someone to learn and learn something yourself. It is more difficult to work individually. An entrepreneur is someone who gathers people around him to create something together" (S1).

Students also pinpointed Interdisciplinary reflections as the formats which they found the most interesting. Even though the tasks during this course were challenging, it helped to develop an understanding of interaction of these disciplines and develop a whole picture of the SKOLKOVO modules.

"I remembered Interdisciplinary reflections, because they summarized everything. It was a repetition of the material, and we remembered everything that we studied. When summed up, everything fits into a single picture in my head" (S4).

"I remember the format of Interdisciplinary reflections, when they gave me a topic and I had to prepare a presentation on this topic in an hour. It was a shock, because I had to remember everything, understand how to present it, and then arrange it into a presentation, it was quite difficult" (S11).

Talking about MIPT courses, students highlighted laboratory works during which they had an opportunity to put theoretical material to practice.

"Laboratory work was interesting, it implies teamwork, interaction with the material, application of knowledge in practice" (S5).

"I enjoyed laboratory work in Biology courses. I do not have a strong background in biology in general, and it was hard for me to remember this large amount of information. Laboratory work helped a lot, because it helped to remember some aspects through practice" (S1).

But overall, they stated that teaching activities and class formats in MIPT are less interactive and consist mostly from traditional lecture-seminar formats. However, it is important to mention that some students (even though their number is low) highlight the importance of such formats for learning, as they are aimed at developing fundamental and theoretical knowledge which will be put to practice later.

"In MIPT education is traditional: lectures, seminars. But this is just a learning format that contains a large amount of information. It is unlikely that you can fit it into the interactive game" (S8).

"For me personally, it is difficult to work at seminars without a lecture, so this is one of the most necessary formats in education" (S16).

They also pinpointed that course instructors play a crucial role in the engagement in the learning process. For example, some students stated that they enjoyed the Introduction to Mathematical Analysis course because the course instructor was able to engage students in the learning process, and they liked his style of teaching. They also stated that because of him they developed an interest to deeply study this subject.

"I enjoyed the teaching style of the professor on the Introduction to Mathematical Analysis course. After his lectures, you fall in love with math analysis" (S1).

"I remember the lecturer and seminarian on Introduction to Mathematical Analysis course. They instilled love for math analysis, their lectures, jokes helped to better understand the material" (S11).

It is interesting that for the questions "what material was easier to learn and why" students focused on the efficiency of the educational model in their answers. Students were able to name some theories and concepts, both from MIPT and SKOLKOVO courses, and explain what these theories and concepts include. However, they stated that from all the learned material they remember better only those theories and questions, which they prepared and explained during exams. Students put in a lot of effort to prepare for exams and control work, however, after they pass them, this information is no longer relevant for them, and it starts to fade away from the memory eventually.

"There were control works, we prepared a lot for them, but on the next day forgot everything. Some information remained, but in general, I cannot say that it is a whole body of information. I remember only some statements and details" (S5).

"This is the characteristic of the education in MIPT, you need to study hard for tests and exams. But it is difficult to say how useful all this will be in the future" (S8).

"Everything depends on time, you need to sit and learn" (S6).

From SKOLKOVO courses students focused on remembering the material which can be put to practice. Most of them pinpointed Behavioral Economics and some concepts which explained how people make decisions, and they see how they can potentially apply this knowledge in their future.

"I liked the material which can be applied in practice, for example things that influence behavior and its formation. I liked this topic, so I tried to take as much as possible" (S9).

"I remember examples of how the material can be used in life" (S2).

Talking about MIPT courses, students pinpoint that the learning material here is built up in sequential format: from easy and fundamental knowledge to more advanced. Therefore, one material can correlate with another and support the previous knowledge and consequently retain it.

"In MIPT the educational process is built in such a way that everything constantly emerges from each other in layers. Firstly, we learn something simple and then goes more and more complicated material, so in this format it is difficult to completely forget something" (S5).

But the overall answer of the students was that they can remember and explain some theories, but this knowledge right now feels rather fragmentary, and it is hard for them to remember them in detail.

"I remember individual topics tables, but here specific calculations, control works, I do not remember them" (S4).

Finally, talking about the question "what challenges you faced in both formats of education and why" students highlighted the following aspects. In SKOLKOVO courses, students highlight that these courses pass rather fast and there is not enough time to retain knowledge fully and interact with it deeper.

"In SKOLKOVO we do not have time to internalize information fully. In general, you try to dive in, but a week is not enough for this" (S14).

They also pinpointed that in some courses the final tasks were much harder than the material, which they studied during the course, and it had put an additional pressure on them.

"From SKOLKOVO courses, it was difficult to solve the final test in Behavioral Economics. We had much easier material during the course, and in the final test the tasks were very difficult" (S1).

The educational expectations of course instructors were also sometimes not clear, and students simply did not understand what results course instructors wanted to observe and, therefore, they did not understand the feedback.

"Sometimes, I did not fully understand, both in SKOLKOVO and MIPT courses, what the professors expected, from me and what feedback they tried to convey to me" (S15).

"At the beginning it was not clear what the professors wanted from us in Biology course, they did not expect that we would have such a small amount of background knowledge. Sometimes it was hard to communicate with them" (S9).

Talking about MIPT courses, some students stated that they cannot retain any knowledge from Introduction to Mathematical Analysis. They study the material, but it fades away from the memory easier than any other information.

"I cannot learn it, I can explain some concepts, but in general, memorization of information is not happening, I always forget it" (S10).

Also, students struggled with the disciplines in which they had a weak background knowledge, which is Biology. Most of the students were enrolled in the program based on the Physics and Mathematics exams and, therefore, they faced some difficulties in studying Biology. They also pinpointed that MIPT's Biology course instructors were not ready to work with students with such low background knowledge, and tried to adapt the course. This led to the fact that the material inside the course was mixed with some material from chemistry and different approaches for teaching of lecturers and seminarians. They had different requirements for students, and in the end it was difficult for students to understand what specific results they should demonstrate.

"They tried to put a lot of chemistry into the Biology course, but it's hard to say that they did it well" (S8).

"Biology was very difficult, because we have weak background knowledge in it" (S10).

"I personally had to catch up Biology, memorizing everything for the exams" (S15).

"Evolutionary Genetics in SKOLKOVO was a complex material, Biology in MIPT was easier, because it included fundamental knowledge. In SKOLKOVO we had to study neurobiology without a solid background" (S2).

From this analysis of the interviews, it is possible to pinpoint the following main statements:

- Students value applicability of knowledge, so they mostly focus on memorizing the material which will be useful for them in their future careers.
- Students enjoy interactive and group work because it helps them to develop skills and form their cognition, necessary for the business leaders.

- In most of the cases, the motivation for students to study the material was predetermined by the necessity to pass exams. It might influence the retention of knowledge to some extent, because after passing the exams, students lose the purpose to retain this knowledge further and in the end it retains in fragments.
- Students faced difficulties in studying the material which was new to them and in which they did not have solid background knowledge.
- Students have solid expectations from the MIPT education, however expectations for SKOLKOVO courses were not clear.
- Students press on the fact that in SKOLKOVO courses there is not enough time to fully engage with the discipline and some information was given in fragments, therefore, they remember it also in fragments.

In order to correlate these statements with the actual knowledge retention, the analysis of individualized knowledge tests was conducted. Answers of students were compared with the answers from the previous semester and the answers provided by the course instructors.

The analysis of the individualized tests was conducted in the following aspects:

- Overall knowledge retention.
- Overall level of procedural knowledge retention.
- Overall level of conceptual knowledge retentions.
- Overall level of factual knowledge retention.
- Overall knowledge retention in the Biology course.
- Overall knowledge retention in the Introduction to Mathematical Analysis course.
- Overall knowledge retention in Behavioral Economics course.
- Overall knowledge retention in Evolutionary Genetics course.
- Overall knowledge retention in SKOLKOVO School of Management courses:
    - Retention of procedural knowledge in SKOLKOVO School of Management courses;
    - Retention of factual knowledge in SKOLKOVO School of Management courses;

- Overall knowledge retention in MIPT courses:
    - Retention of procedural knowledge in MIPT courses;
    - Retention of factual knowledge in MIPT courses;
- For each student:
    - Total knowledge retention in all disciplines;
    - Knowledge retention in Biology block;
    - Knowledge retention in Mathematical block
    - Retention of procedural knowledge;
    - Retention of conceptual knowledge;
    - Retention of factual knowledge
    - Retention of knowledge in SKOLKOVO courses.
    - Retention of knowledge in MIPT courses.

Overall knowledge retention was calculated by taking all the questions and tasks and identifying what percentage of this number takes the right answers. Overall, this study included 343 questions, 159,5 of which students answered correctly. Therefore, the overall knowledge retention 46,5% (Figure 4).

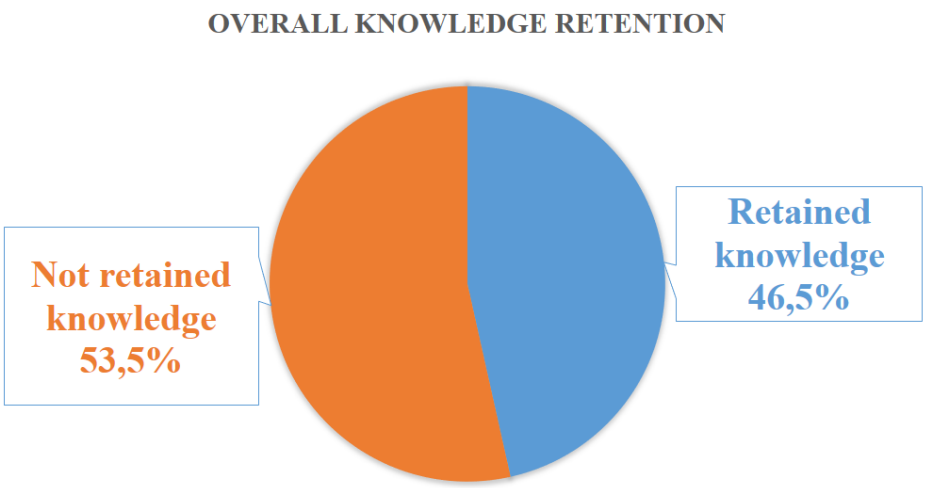

Fig. 4. The percentage of overall knowledge retention

Overall retention of the procedural knowledge includes all the tasks which are required to perform calculations. These tasks are primarily from such courses as the

Introduction to Mathematical Analysis and Behavioral Economics. It is important to mention that in these tasks students often made mistakes in calculation even though they remembered the theories and procedures correctly. Therefore, if a student remembered the process or applied theory correctly, but made a mistake in calculations, the task was counted as half solved (0,5), rather than a fully correct answer (1). Thus, the overall number of procedural knowledge questions was 134 and the number of correct answers was 49,5. Therefore, the percentage of the overall procedural knowledge is 36,9%.

Overall retention of the conceptual knowledge included the task from the Evolutionary Genetics course, where a student was asked to describe a physical reaction (how a person jerks back when touching a hot iron or drawing a scheme and describing the work of the brain's match detector). The total number of questions was 15, while the number of correct answers was 7. Therefore, the retention of conceptual knowledge is 46,6%.

Overall retention of the factual knowledge consisted of the tasks related to naming a theory or concept or answering close-ended questions (Yes\No). These questions included tasks from Evolutionary Genetics, Biology, and Behavioral Economics. The total number of questions was 194, while the number of correct answers was 103. Thus, the retention of factual knowledge is 53,1 (Figure 5).

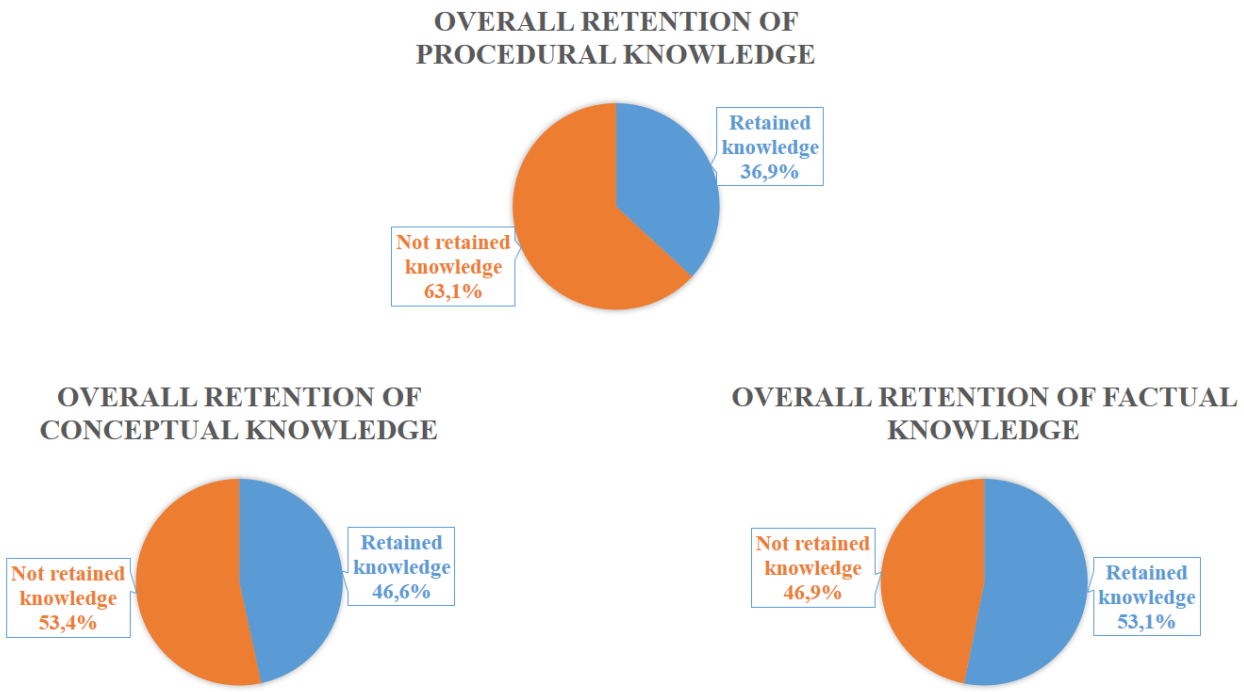

Fig. 5. Overall retention by the levels of knowledge.

Overall knowledge retention in Biology course included only questions for the MIPT's Biology course. These tasks were based on the laboratory work report, which gave a description of the materials and the processes, while students had to name the process which is occurring. The total number of questions was 16, while the number of correct answers was 7. Therefore, the percentage of knowledge retention in Biology course is 43,7%.

Overall knowledge retention in the Introduction to Mathematical Analysis course included the final tasks from the MIPT's course. The total number of questions was 48, while the number of correct answers was 16,5. As it was mentioned before, for this course it was important to look not only at the correctness of the final answer, but also on the ability of the student to apply theories and concepts. Therefore, if a student had a correct answer it was counted as 1, while in the case of miscalculation but with a correct application of the theory it was counted as 0,5. Therefore, the overall knowledge retention in the Introduction to Mathematical Analysis course is 34,3%.

Overall knowledge retention in Behavioral Economics course included the final test from the SKOLKOVO School of Management's course. The total number of

questions was 110, while the number of correct answers was 46. Therefore, the overall knowledge retention in Behavioral Economics course is 41,8%.

Overall knowledge retention in Evolutionary Genetics course included the final test from the SKOLKOVO School of Management's Evolutionary Genetics course. The total number of questions was 169, while the number of correct answers was 90, therefore the overall knowledge retention in Evolutionary Genetics course is 53,2% (Figure 6).

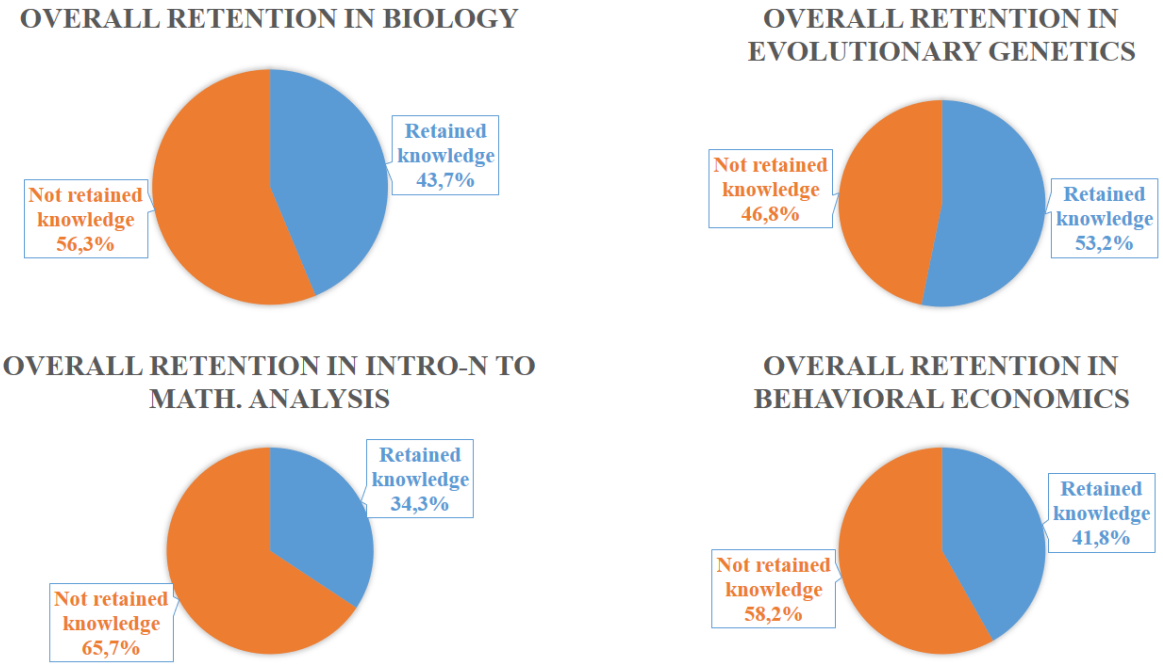

Fig. 6. The retention of knowledge by disciplines

The next step in the analysis is identifying the proportion of knowledge retention in SKOLKOVO School of Management and MIPT. It is important to mention that this analysis does not compare in which types of courses knowledge retention is higher, rather than identifying the level of knowledge retention in each type of courses separately.

Overall knowledge retention in SKOLKOVO School of Management's courses included questions from Evolutionary Genetics and Behavioral Economics courses. The overall number of questions was 279, while the number of correct answers was

136. Thus, the percentage of knowledge retention in SKOLKOVO School of Management's courses is 48,7%.

It is important to understand what type of knowledge from this percent had a higher level of retention. Therefore, the studied SKOLKOVO School of Management's courses were divided in factual and procedural knowledge.

The retention of procedural knowledge in SKOLKOVO School of Management's courses included questions which required performing the calculations and application of theories. The number of these types of questions from all 280 questions SKOLKOVO courses was 86, while the number of correct answers was 33. Thus, the retention of procedural knowledge in SKOLKOVO School of Management's courses is 38,3%.

The retention of factual knowledge in SKOLKOVO School of Management's courses included questions which required naming a process, concept, or theory or answering close-ended questions. The number of these types of questions in SKOLKOVO courses was 178, while the number of correct answers was 96. Thus, the retention of factual knowledge in SKOLKOVO School of Management's courses is 53,9% (Figure 7).

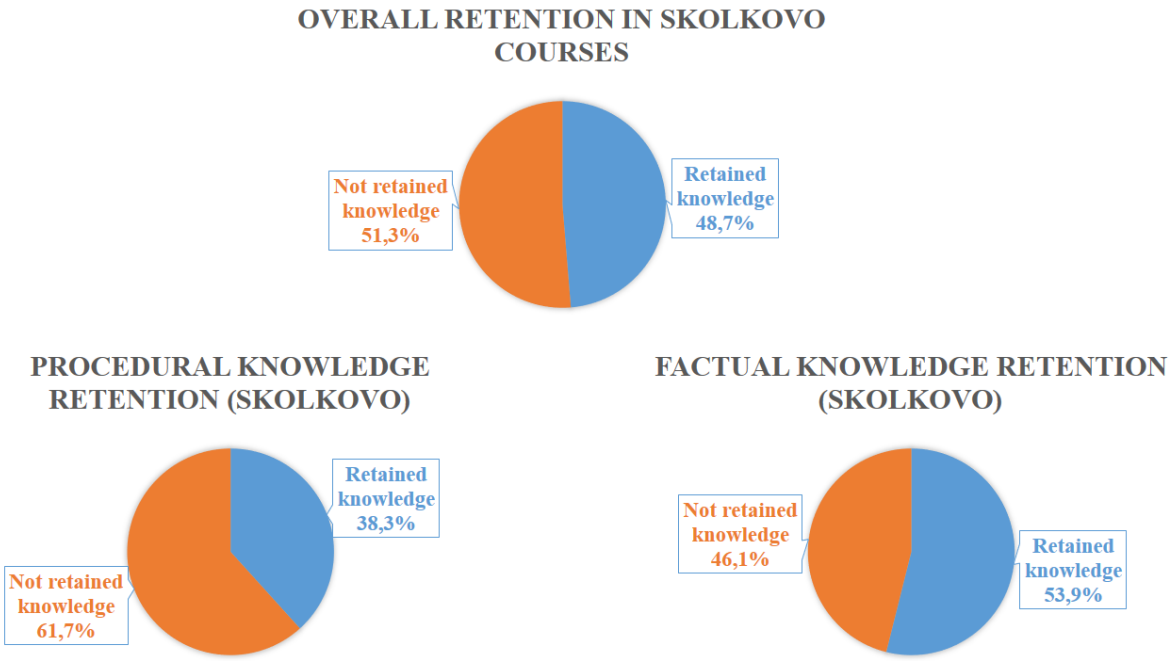

Fig. 7. Knowledge retention in SKOLKOVO courses.

Overall knowledge retention in MIPT's courses included questions from Biology and the Introduction to Mathematical Analysis courses. The overall number of questions was 64, while the number of correct answers was 23,5. Thus, the percentage of knowledge retention in MIPT's courses is 36,7%.

Talking about the procedural knowledge retention in MIPT's courses, it consisted of the Introduction to Mathematical Analysis tasks. The overall number of these types of tasks is 48, while the number of correct answers is 16,5. Thus, the percentage of procedural knowledge retention is 34,3%.

Talking about the factual knowledge retention in MIPT's courses, it consisted of the Biology tasks. The overall number of these types of tasks is 16, while the number of correct answers is 7. Thus, the percentage of factual knowledge retention is 43,8% (Figure 8).

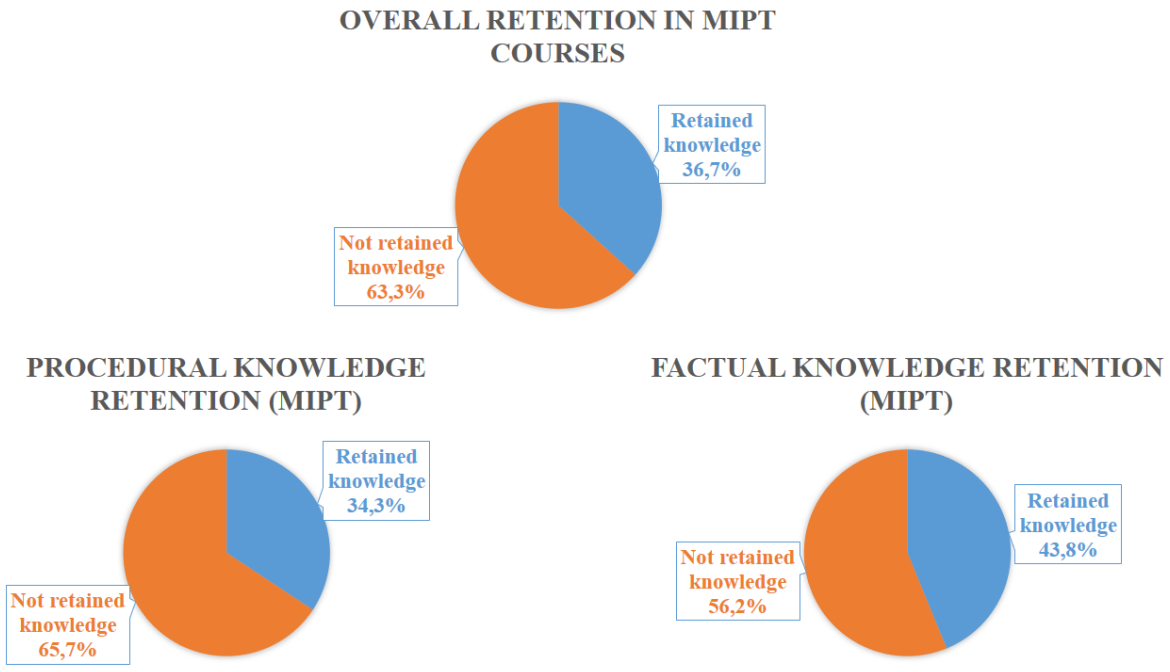

Fig. 8. The retention of knowledge in MIPT courses.

Other figures which are important to consider are the percentage of knowledge retention in all disciplines, in biological disciplines, in mathematical disciplines and the retention of different levels of knowledge individually for each student. These figures are presented in Table 3.

Table 3

Knowledge retention for each student

Student	Overall	Biological disciplines	Mathematical disciplines	Procedural knowledge	Conceptual knowledge	Factual knowledge	SKOLKOVO courses	MIPT courses
S1	28,5%	41,6%	11,1%	0%	0%	46,1%	29,4%	25%
S2	37,5%	41,6%	11,1%	30%	100%	46,1%	45%	25%
S3	47,7%	61,5%	27,7%	27,7%	0%	61,5%	55,5%	12,5%
S4	45%	58,3%	25%	33,3%	0%	50%	50%	50%
S5	50%	63,6%	33,3%	14,2%	100%	66,6%	56,2%	25%
S6	43,1%	54,5%	31,8%	31,8%	-	54,5%	38,8%	62,5%
S7	63,8%	66,6%	61,1%	56,2%	100%	66,6%	71,4%	37,5%
S8	50%	53,8%	45,8%	45%	0%	57,1%	47,6%	62,5%
S9	62%	75%	50%	59,1%	100%	61,5%	61,9%	62,5%
S10	60%	69,2%	42,8%	33,3%	100%	69,2%	68,7%	25%
S11	57,8%	80%	22,2%	28,5%	100%	72,7%	60%	50%
S12	31,8%	30,7%	33,3%	42,8%	0%	28,5%	33,3%	25%
S13	38,1%	27,2%	50%	50%	100%	25%	41,1%	25%
S14	30,4%	25%	45,4%	44,4%	0%	30,7%	36,8%	25%
S15	39,4%	40%	38,8%	21,4%	0%	54,5%	40%	37,5%
S16	52,2%	54,5%	50%	50%	0%	60%	55,5%	37,5%

From this table, it is possible to see how individual learning capacities influence the retention of knowledge. For example, S1 stated that Introduction to Mathematical Analysis was one of the hardest disciplines for her, since it was difficult for this student to remember the application of formulas. Therefore, she skipped the majority of tasks in this block and consequently have one of the lowest percentage of retained knowledge in this block and overall retention level.

On the other hand, the highest knowledge retention in the mathematical block has S7. In the reflection of this student, it was pinpointed that they worked hard and

put a lot of effort in this particular course, because it was the beginning of their studies and they wanted to do their best.

The highest overall knowledge retention has S9. During the interviews, this student was able not only to name some specific concepts, theories, and information from all the tested courses, but also connect it with possible application of these concepts in future career, as well as explain how they work.

The lowest knowledge retention in biological disciplines has S14. In his preliminary reflection, this student stated that in MIPT courses there is usually a huge influx of information which might be challenging to remember and understand how to do it effectively. Since the majority of students have weak background knowledge in Biology and taking into consideration the fact, that Biology was one of the first courses that were taught in MIPT, it is possible to say that in this case student did not have enough time to adapt to new academic environment which consequently influenced the knowledge retention in the material, which student did not know well previously.

On the other hand, the highest knowledge retention in biological disciplines has S11, which also pinpointed difficulties, connected to the weak background knowledge in Biology. However, in the reflection of this student, it was highlighted that practical laboratory works played their role in the internalization of knowledge and helped the student to retain some information.

As it was previously stated, S1 faced challenges in remembering the application of the formulas, so this student has the lowest retention rate in procedural knowledge as well.

The highest retention of procedural knowledge has S9. Aside from the applicability of knowledge, which was highlighted by this student previously, it was pinpointed that interactive format of some courses helped them to retain knowledge.

The highest retention of factual knowledge has S11. In the reflection on the question related to the ability to remember the material, this student was able to name basic concepts and theories in all the courses, which were under study, however, there were mistakes in calculations. Also, this student was able to answer the majority of theoretical questions correctly.

On the other hand, the lowest level of factual knowledge retention has S13. The main difficulty in the learning process, that was pinpointed by this student, that it was hard to learn and understand some facts from short courses, since they passed fast and there was not enough time to deeply engage and learn the material.

Talking about knowledge retention in SKOLKOVO and MIPT courses, the lowest knowledge retention in SKOLKOVO courses has S1. Even though this student highlighted the interactive format of SKOLKOVO courses which were interesting and engaging, it was pinpointed that the material which was given to students during these courses seemed to be difficult. Behavioral Economics, for example, were connected with complex mathematics and Evolutionary Genetics was taught to them without consideration that the students have weak background knowledge. At the same time in MIPT courses this circumstance was considered, therefore, MIPT's Biology seemed to be easier for this student.

The highest retention in SKOLKOVO courses has S7. It might be due to the fact that this student stated that it is easier to remember the first set of SKOLKOVO courses, since they were introductory, and they started to explore new formats of learning.

The lowest knowledge retention in MIPT courses has S3. This student stated that it was not interesting for them to do the practical tasks in MIPT courses, because it included solving a huge amount of mathematical tasks, which was boring. On the other hand, this student enjoyed learning theories, since this material was more diverse and interesting for them.

The highest retention in MIPT courses is S6, S8 and S9. It is important to mention that these students had well-developed expectations of studying in a technical university and were prepared for the challenges that they might potentially face. These students also stated that SKOLKOVO courses are too short and, therefore, there is not enough time to deeply-engage in the knowledge which is being taught to them.

From this analysis, it is possible to observe that students have different learning styles and their memory function in different ways. While some students retain more facts, others tend to remember specific applications of these facts. While some students value interactive formats of learning, others prefer the fundamental nature of

knowledge and deeper engagement in it. This analysis gives an important profile of the student body which might be potentially used for further adaptation of the learning process and enhancement of knowledge retention. The graphic representation of students' individual learning dynamics is presented on Figure 9.

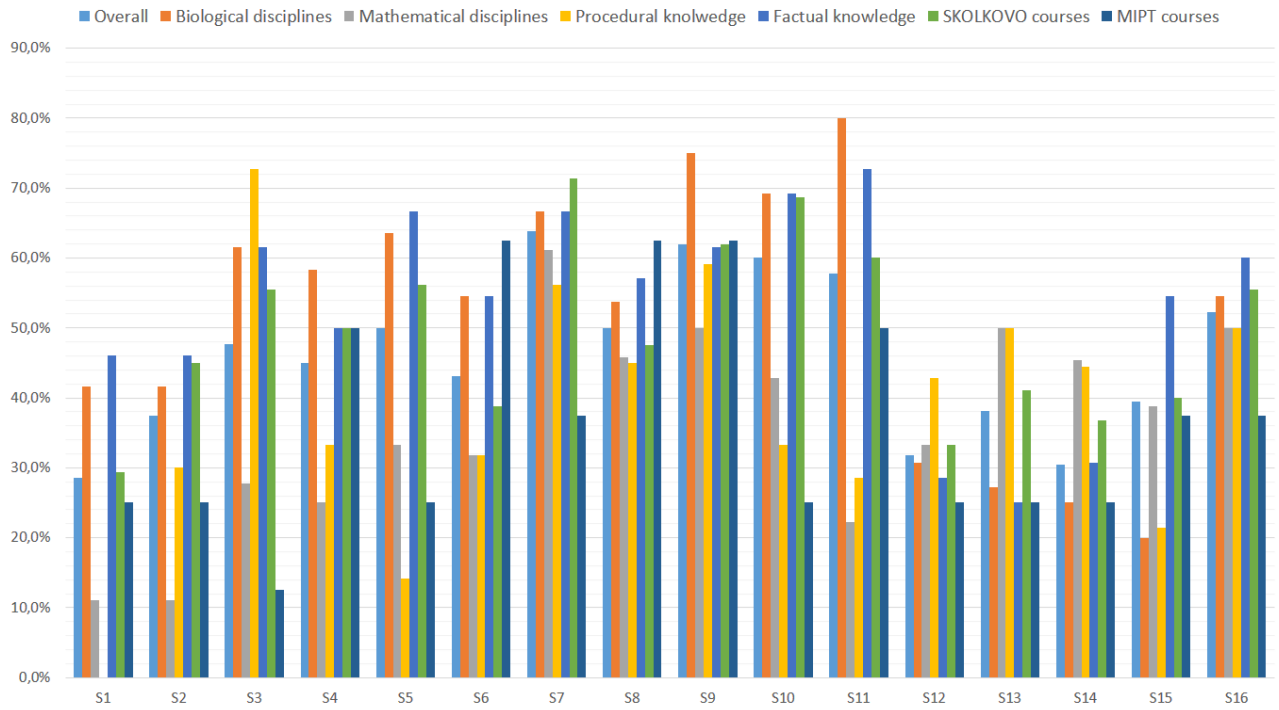

Fig.9. Knowledge retention for each student.

From this analysis, it is possible to make the following conclusions:

- The average retention rate in biological disciplines is 52,6%;
- The average retention rate in mathematical disciplines is 36,2%;
- The average retention rate for procedural knowledge is 35,4%;
- 7/16 students were able to answer questions, related to the conceptual knowledge, correctly;
- The average retention rate for factual knowledge is 53,1%;
- The average knowledge retention for SKOLKOVO courses is 49,4%;
- The average knowledge retention for MIPT courses is 36,7%.

Thus, it is possible to make the following conclusions:

- 13/16 students have higher knowledge retention in biological disciplines;
- 13/16 students have higher retention of factual knowledge;

- 12/16 students have higher knowledge retention in SKOLKOVO courses.

Results discussion

From the analysis of the interviews and the analysis of test results, it is interesting to pinpoint three main findings.

Firstly, the higher knowledge retention in biological disciplines. Even though students do not have a strong background in Biology, the retention rate in Biology and Evolutionary Genetics is higher than in Behavioral Economics and Introduction to Mathematical Analysis. Even though students stated that they faced significant difficulties in studying Biology or Evolutionary Genetics, they remember the information from these courses better. This fact might be due to the fact that knowledge tests in Biology mostly included tasks on the factual knowledge, which students on average retained better. The tasks for Biology course included knowledge which the students acquired during laboratory works and, thus, are based on practice, which they previously performed.

Secondly, even though students emphasized the fact that SKOLKOVO courses are rather introductory, not fundamental, pass fast and, therefore, they remember less information from them, the retention rate in these courses is higher than in fundamental MIPT courses. This fact also relates to the applicability of knowledge as one of the dimensions of knowledge retention, as well as to the teaching activity and students'motivation. From the analysis of the interviews, it is visible that students value the applicability of knowledge in their education, thus they concentrated on memorizing the information, which they saw to be useful in their future careers. Moreover, students highlighted that SKOLKOVO courses were more interactive and engaging. Students reflect on this educational experience as fulfilling in terms of applicable skills, since they value group work as a possibility to develop leadership skills. At the same time, student's description of their motivation to study on MIPT courses was, in most of the cases, determined by the fact that students need to pass exams. In this sense, students engaged with the knowledge from the courses intensively, primarily before the exams. None of the students highlighted the applicability of this knowledge; however, they see it as an integral part of their

education. Therefore, it is possible to say that applicability of knowledge, teaching activity and students' motivation play a significant role in knowledge retention.

Finally, talking about the retention of different levels of knowledge, it is important to highlight that students were able to retain knowledge that is more factual rather than other levels of knowledge. In the students' reflection on their educational experience, they pinpoint that they remember information from both types of the courses in fragments. They can recall some facts and give a short description, but it is hard for them to remember information that is more advanced. This is due to the fact that before the research, students were asked to not revise any information from these courses and, considering the fact that it is the nature of memory to forget the information that is not being actively used, it is only natural that students can remember only facts. At the same time, the application of these facts is a higher level of knowledge, according to Revised Bloom's Taxonomy, which requires a deeper engagement with it. Students need firstly remember the application of some theory or concept before actually applying it. Nevertheless, since students themselves pinpoint that they can remember only basic information from the courses. Therefore, it was hard for the majority of students to show a significant retention of procedural knowledge as well as conceptual knowledge.

Another concluding fact, which is important to mention, is that even though students did not revise the information from the tested disciplines, the overall retention is close to 50% percent that might potentially mean that the length of the course and time after course completion did not significantly influence the knowledge retention in this particular program. At the same time, applicability of knowledge, teaching activity and students' motivation to study played a major role in the retention of knowledge within the program.

CONCLUSION

Knowledge retention studies are an important tool for providing evidence on the effectiveness of an educational model and the possibilities to enhance it. However, it should be considered that knowledge retention is a multidimensional process and requires consideration of various factors that can influence it. In this thesis, the main domains of knowledge retention were derived from the literature review and served as a basis for developing a methodological framework for studying knowledge retention in a SKOLKOVO-MIPT Bachelor of Business Administration program. It was possible to consider all the derived dimensions of knowledge retention in the methodological framework:

- Teaching activity and students' motivation – the individualized tests included tasks from more interactive courses and from more traditionally organized courses.
- Individual learning capacities – the individual learning performance was taken into account on the stage of the knowledge test preparation. Also, the study included the retention of different levels of knowledge for each student, which also signifies what specific type of knowledge each student remembers better.
- Time after course completion – knowledge tests included knowledge from the courses which were finished by students in the first and second semesters. Moreover, there is a difference in time after SKOLKOVO and MIPT courses completion in the framework of the study: the study was conducted six months after completion of chosen SKOLKOVO courses and four months after completion of MIPT courses. It is worth mentioning that even though there was a significant time gap at the time the individualized knowledge tests were reintroduced to students, the retention of knowledge in SKOLKOVO courses was higher due to the interactive nature of classes and the material which students saw to be useful in their future careers.
- Cognitive and knowledge dimensions – individualized knowledge tests included different types of tasks that correspond to different levels of knowledge and cognitive processes.

- Applicability of knowledge – reflection of students on the further applicability of the knowledge and how it helped to retain it. According to the analysis of the results, in the case of SKOLKOVO-MIPT Bachelor of Business Administration program, this dimension played a major role in knowledge retention.
- Course length – the study included more traditional semester-long courses and more not-traditional short courses. However, in the framework of this study, this particular dimension did not play a major role in the knowledge retention.

Thus, it is possible to say that the derived dimensions of knowledge retention include the factors that play a significant role in knowledge retention, however they have a different level of influence on this process. This level of influence might be determined by the students' profile and their motivation to study specific knowledge or to acquire specific skills. In addition, it might be determined by the specific learning environment or educational model, which might potentially increase the influence of one factor and reduce the influence of other factors.

The derived dimensions of knowledge retention are universal and can be applied to different courses and educational environments, since these dimensions include the main aspects that influence the retention of knowledge.

In this thesis, the derived dimensions were applied to shape the research design of knowledge retention study in SKOLKOVO-MIPT Bachelor of Business Administration program. With the help of the derived dimensions, it was possible to identify how current course organization inside the program influences knowledge retention of students. It was also possible to identify the exact percentage of knowledge retention and, most importantly, the dimensions of knowledge retention, which influenced this process. Even though the knowledge retention in MIPT courses is lower than in SKOLKOVO courses, according to the analysis of results, some students still pinpointed that it is an integral part of their education, which gives fundamental knowledge in disciplines and helps to establish a comprehensive worldview. In this sense, it is possible to say that the program is oriented not only on the education of the future business leaders in the direct meaning of this word. The program integrates three disciplinary components and, therefore, it is possible to say that the program aims at

development of a specific worldview, which will help the students to become innovators. Talking about the meaning of the results to the SKOLKOVO-MIPT Bachelor of Business Administration program, it was found that students' value the applicability of knowledge and interactive teaching activities in the educational process. However, due to the nature of university education, it is hard to give students only practical skills without general or fundamental education in specific fields. Even though the retention of knowledge in MIPT courses is lower, it means that there is a space to organize these courses in a way that they support fundamental learning.

There were a number of limitations in the framework of this thesis, which are determined by the time limitations, and the lack of ability to include more courses, which were finished recently to diversify the data on the influence of time after course completion on the knowledge retention. Also, another main limitation is the lack of course instructors' engagement in the study process. Because of that, it was crucially important to choose the tasks which could be analyzed without their involvement and, therefore, the analysis of cognitive and knowledge dimensions are limited by procedural, conceptual and factual knowledge. However, with the active engagement of course instructors in the studies of knowledge retention, will help to diversify the types of tasks and include more cognitive and knowledge dimensions in the study. Another limitation, which is important to mention, is the format of the knowledge test as a tool to study knowledge retention. Even though it is one of the most frequently used tools to study knowledge retention, it is primarily used to study retention in one or two courses. However, in the framework of this study, four courses were included, and it took approximately 2 hours for each student to solve the tasks, which can potentially put additional pressure on students. Therefore, it is important to design specific tasks for this kind of knowledge test, which include more than two courses, in order for it to be short and provide reliable data on knowledge retention.

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