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RESEARCH ARTICLE

Didactic modeling for teaching technological university students the rules of foreign language texts reading

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Abstract

Objectives. The work set out to develop didactic models for teaching French reading rules to first-year students from scratch, followed by a choice of the appropriate model to use in teaching.

Methods. The application of didactic models developed using tools such as regression analysis and mathematical theory of learning along with an experiment on the application of the obtained models in groups of French language learners “from scratch.”

Results. Three obtained models of studying 48 French reading rules over 4, 8, and 16 weeks with 12, 6, and 3 rules per lesson respectively, along with a review of the rules learned in the previous lesson, are presented for comparison and analysis. The influence of various factors such as students’ linguistic abilities, their levels of anxiety, previous language learning experience, etc., on the effectiveness of all three models were also taken into account. Based on the results of these analyses, the optimal learning model was chosen.

Conclusions. The average student learned reading rules more efficiently during an eight-week course when the rules were regularly reviewed at each lesson until the end of the semester. When studying reading rules for 16 weeks, students failed to review some material at the end of the semester, with fewer rules being reviewed in lesson. During a four-week study, students confused the rules and had difficulties to remember them due to cognitive overload. In the presence of adverse factors (weak ability and motivation, lack of independent work, etc.) training results were low regardless of the model chosen. On the contrary, under favorable conditions (good abilities, motivation, etc.) the learning model was turned out to be unimportant.

Keywords: didactic model, reading rules, French language, technological university

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НАУЧНАЯ СТАТЬЯ

Дидактическое моделирование обучения студентов технологического университета правилам чтения иноязычных текстов

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Резюме

Цели. Целями работы являются разработка дидактических моделей процесса преподавания правил чтения французского языка, изучаемого студентами первого курса с нуля, и выбор оптимальной модели для дальнейшего использования в обучении.

Методы. Применение дидактических моделей, разработанных с привлечением таких инструментов, как регрессионный анализ, математическая теория обучения и эксперимент по применению полученных моделей в группах, обучающихся французскому языку с нуля.

Результаты. Для сравнения и анализа представлены 3 полученные модели изучения 48 правил чтения во французском языке в течение 4, 8 и 16 недель по 12, 6 и 3 правила за одно занятие, соответственно, с повторением правил, изученных на предыдущем занятии. Учитывалось также влияние различных индивидуальных факторов на эффективность всех 3 моделей (лингвистические способности студента, уровень тревожности, предыдущий опыт изучения языков и т.п.). В результате была выбрана оптимальная модель обучения.

Выводы. Среднестатистический студент эффективнее усвоил правила чтения при восьминедельном обучении, когда последующие 8 недель (до конца семестра) правила регулярно повторялись на каждом занятии. При изучении правил чтения в течение 16 недель студенты не успели повторить некоторый материал в конце семестра, меньше правил повторялось на занятиях. При четырехнедельном изучении студенты путали правила, плохо их запоминали из-за когнитивной перегрузки. При наличии неблагоприятных факторов (слабые способности и мотивация, отсутствие самостоятельной работы и т.п.) результаты обучения оказались низкими независимо от выбранной модели. Напротив, при благоприятных условиях (хорошие способности, мотивация и т.п.) оказалось, что модель обучения не играет решающей роли.

Ключевые слова: дидактическая модель, правила чтения, французский язык, технологический университет

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INTRODUCTION

The modern educational paradigm is undergoing a transformation that involves a comprehensive and coordinated overhaul of key aspects of learning, including learning objectives, curricula, teaching methodology, and the structure of educational activities. On the one hand, a digital transformation is taking place, which refers to the integration of digital technologies, the creation of digital educational platforms, and the introduction of artificial intelligence into the teaching process in order to optimize the management of educational processes [1–3]. On the other hand, the development of mathematical and didactic models, including those that replace experimental research, along with the introduction of mathematical methods and didactic modeling methods into the humanities, signify a transformation in professional training at universities, which is particularly relevant in the teaching of foreign languages at technical universities, where the educational emphasis is on the study of core disciplines. Here, the determination of the structure of the curriculum, work program, teaching materials, and mathematically verified prediction of learning outcomes for each study group and individual student are designed to optimize the processes of teaching and learning a foreign language. Modern didactic models provide an equivalent description of objects, their relationships and dynamics, as well as the parameters of functional dependencies. Thus, didactic modeling provides tools for objective assessment and modeling of foreign language teaching.

The purpose of the present study is to model the process of teaching French reading rules to first-year students starting from scratch and to determine the optimal model.

The main research method is the use of didactic models, which are developed using various methods including regression analysis and mathematical learning theory. The models obtained in this way were experimentally tested in different groups of RTU MIREA students who had commenced a course of French language study.

The novelty of this research consists in the current apparent lack of any formal-logical pedagogical studies involving comparable models.

The practical significance of the study lies in the prospect of managing the educational work of students at a technological university and selecting the optimal educational trajectory. This is achieved by analyzing the influence of various parameters on the learning process and identifying their interrelationships.

LITERATURE REVIEW

The study was conducted within the framework of educational analytics aimed at studying the educational

process and the quality of education. In previously published works, educational analytics tends to be considered solely from the point of view of the application of information platforms [1], relevant information support for teachers and students, assessment of the latter's success [4], and the development of information systems that predict students' academic performance based on three parameters [5]. The digital transformation of education involves the use of educational analytics to create a system for managing the educational process [1, 3]. In the case under consideration, an example of such a system is based on mathematical calculations, which can then be converted into digital format and posted on university learning platforms. When building a model using information platforms and mathematical calculations, various types of data are taken into account, which can be constant or variable. On this basis, the educational process management system is built and learning analytics tools are developed, leading to the selection of optimal curricula and work programs.

Works [6–8] present developed mathematical and computer models for researching the educational process based on general systems theory and the axioms of mathematical learning theory. Modeling of weakly formalized systems covering aspects of the selection of educational resources, teaching methods, and criteria for evaluating their effectiveness is possible only within the framework of fuzzy cognitive modeling [8–10]. There are works devoted to a stochastic model in which the probability of data can vary.¹ Here methods are also presented for estimating the parameters of this model and examples of its application to various types of data related to the learning process.

Work [10] describes algorithms for creating teaching materials along with training models based thereupon, as well as the “Training Trajectory” program for any discipline and the “Group Trajectory” program. In addition, the work provides an insight into the process of training teachers in the use of mathematical modeling methods.

The review by Tishina [11] notes that the educational process is a complex system determined by numerous and constantly changing factors, which requires constant adjustment of the methods used with the help of a specific algorithm and mathematical models, which should be experimentally verified, since models “cannot be absolutely adequate to the object.” For the effective selection and compilation of a mathematical model of learning, the author recommends using analytical methods developed within the framework of graph theory.

¹ Bush R.R., Mosteller F.A. *Stochastic Model with Applications to Learning*. https://projecteuclid.org/download/pdf_1/euclid.aoms/1177728914. Accessed April 24, 2024.

Researchers Kiriy and Chan Van An [6] propose a mathematical model designed for studying the process of foreign language acquisition. This model, based on Kolmogorov's equations, establishes the dependence of a student's level of language proficiency on their initial training, learning speed, and forgetting speed.

In his study, Mayer [7] provides a fairly detailed analysis of a teacher-student interaction system, examining both linear and nonlinear approaches to learning modeling, as well as models describing the process of knowledge acquisition and subsequent information loss.

Study [12], which describes the use of mathematical methods as part of the educational process, examines in detail key factors such as student learning ability, professional competence of teachers, etc. The author identified the relationships between these factors, for example, between technical equipment and the organization of educational material. Concerning the initial parameters, the definition and analysis of student learning ability, as reflected in study [13], appears to be significant. Thanks to the created entrance test and its productive implementation by the authors, this parameter can be considered a "clear" variable, unlike most parameters in the humanities.

Reichle [9] has developed computational models that promote understanding of the cognitive processes involved in word recognition, sentence analysis, coherent text construction, and eye movement control.

Barack and Tsodyks [14] demonstrate various types of learning (classical conditioning, associative memory, free recall) using specific examples. The work examines modeling levels in terms of their connection to empirical data and mathematical concepts that are often found in learning models from an optimization perspective. It is important to note that this work belongs to the field of neuromodeling, rather than purely mathematical modeling.

Study [15] proposes a mathematical model that assesses the completeness of knowledge acquired in all course topics along with the dynamics of learning educational elements over a certain period. It also presents a project for the phased organization of students' educational activities.

The study presented in [16] analyzes various learning models in the context of long-term observation. The results showed that some cognitive abilities can be preserved even in the absence of regular practice. However, this study mainly focuses on the psychological modeling of learning.

Study [17] reflects how averaging individual learning and forgetting curves transforms the overall curves, leading to a conclusion that learning rates may follow different distributions. The authors analyze the

skewness of these distributions to exclude cases of low learning rates.

In [18], a knowledge graph is used to study intelligent adaptive learning, which is interpreted as the leading tool for acquiring, managing, and optimizing the learning process. A proposed knowledge graph model of the "knowledge-resources-goals" type is based on a strong connection between knowledge, learning materials, and educational tasks. The author also proposes a bidirectional model that takes into account both long-term and short-term memory. The study confirms that such a model can be successfully adapted to learning objectives, reorganizes knowledge and resources, optimizes learning trajectories, offers recommendations for selecting materials, and visualizes the cognitive state of learners, thereby increasing the effectiveness of intelligent adaptive learning.

Study [19] proposes a system of personalized recommendations based on subject-specific knowledge graphs, learner profiles (obtained using xAPI²), and feedback on the learning process. The work [20] is dedicated to solving the problem of diversity in generative language theories by applying formal mathematical methods to language analysis.

One of the objectives of the study [21] was to identify the links between the factors that motivate students to continue studying a language. Multiple linear regression analysis was used to test the hypotheses and confirm the validity of the proposed model. This analysis mathematically models aspects such as "the relevance of teaching materials and technologies to learning objectives and available technologies," "the compatibility of the technologies used with students' individual preferences," "the openness and authority of educational institutions offering multimodal language learning," and "students' personal investment in multimodal language education."

Work³ is devoted to the development of the following topics: "Algorithms for language learning using reinforcement," "Asymmetry of differences in language acquisition between adults and children," and "Mathematical modeling of language development within a population."

Paper [22] presents a mathematical model that examines the impact of educational programs. In particular, it considers a model for university students learning English that takes into account variables such as

² Experience Application Programming Interface is a standard for data exchange between educational content and distance learning systems.

³ Rische J.L. *Mathematical Modeling of Language Learning: Dissertation*. University of California. Irvine. 2014, 89 p. <https://escholarship.org/uc/item/0kb837r3>. Accessed August 17, 2024.

the total number of students, the number of students who have chosen a modern learning format, the number of students who have chosen a traditional learning format, and the number of students who have successfully completed the course. The results of the analysis of this model indicate that attempts to solve problems in education can lead to unexpected negative consequences, such as reverse bifurcation and complication of the situation, which implies the possibility of failing to resolve existing educational problems.

Paper [23] considers a mathematical model based on multiple linear regression analysis. This model establishes relationships between the language learning strategies used and the level of English proficiency. The analysis of the model confirmed that it is not necessary to include all existing language learning strategies in the model in order to accurately predict language proficiency.

In the logic of the system-structural approach, the work [24] examines the quantitative characteristics of the educational process, which include learning, system state, the degree of learning, and the accuracy of learning. The proposed mathematical model of the learning process is implemented using software tools.

The software developed and presented in [25] for modeling the teaching of a foreign language analyzes, predicts, and monitors the level of proficiency in a non-native language, obtains approximations to the parameters of a mathematical model of the process of teaching a foreign language, constructs a graph of the progressive change in the probabilities of three states selected by the authors, and facilitates testing with various parameters in order to optimize their values to achieve the target level of proficiency in a foreign language.

In the paper [26], the authors identify previously unknown linguistic features to which certain formal attributes need to be assigned in order to create reinforcement learning algorithms for teaching spoken language.

Unfortunately, as in most similar studies, the mentioned works consider mathematical models of learning in a general form, without their specific application to the process of learning foreign languages.

Among the existing studies, algorithms and models are also presented that work in the field of studying the process of acquiring a foreign language [6, 21, 23, 26].⁴ However, these works determine the level of proficiency in a foreign language, motivation, and language development rather than addressing specific models of teaching specific topics within the framework of

studying foreign languages in general, and the French language in particular.

Thus, the analysis revealed that numerous studies are being conducted in the field of educational process modeling, which aim to strictly formalize vague didactic concepts, objects, and categories. It should be noted that the reviewed studies do not include a didactic model based on teaching French reading rules, designed to identify the optimal learning time and the amount of material covered in a single lesson.

MATERIALS AND METHODS

The study material, which represented an example of modeling educational processes, was based on the reading rules taught to first-year students of all training programs at RTU MIREA, who were studying French from scratch.

The research methods used included regression data analysis⁵ (number of reading rules studied per lesson; number of reading rules repeated per lesson; learning ability of a specific cohort of students) and the construction of a didactic model for selecting the optimal number of rules studied per lesson along with the total number of the lessons devoted to learning and repeating the rules by a specific cohort of students. This didactic model thus describes the relationship between variables and the dependencies between them.

It must be recognized that pedagogical structures have a probabilistic nature and depend on many parameters that cannot be fully, strictly and objectively described [15]. Consequently, the model proposed in this paper is based only on the most essential characteristics of the educational activity system.

DEVELOPMENT OF A DIDACTIC MODEL

Developing a didactic model describing pronunciation rules in French represents a challenging task. The main difficulty lies in the significant discrepancy between the spelling and pronunciation of words. The goal of the model is to formalize the rules for the correspondence between graphic elements and phonetic units.

The rules of the following type were created:

$$L_n + (L_{n+1} (+L_{n+2})) = S_m (+S_k),$$

where L_n (L from French *lettre*—letter) is the first graphic element in the letter combination; L_{n+1} is the second graphic element; L_{n+2} is the third graphic element, if

⁴ Rische J.L. *Mathematical Modeling of Language Learning: Dissertation*. University of California. Irvine. 2014, 89 p. <https://escholarship.org/uc/item/0kb837r3>. Accessed August 17, 2024.

⁵ Dyachuk A.A. *Mathematical Methods in Psychological and Pedagogical Research*. Study Guide. Krasnoyarsk; 2013, 347 p. (In Russ.).

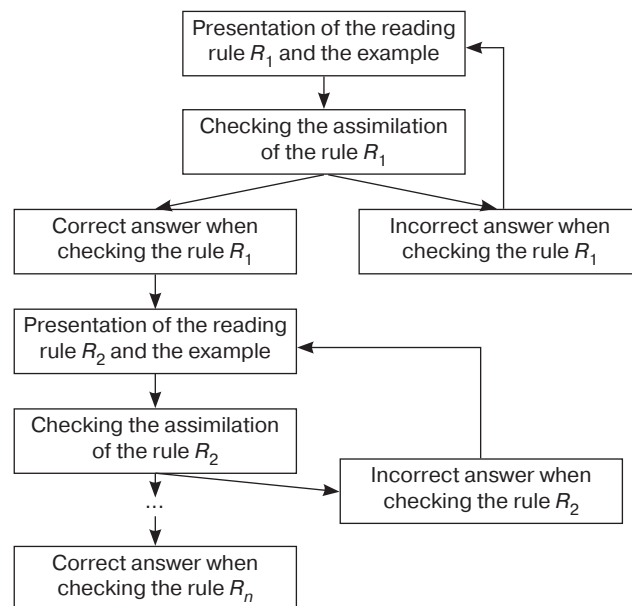


Fig. 1. Sequence of steps for studying the rules of reading

three graphic elements create a letter combination that is read in a special way; $S_{m/k}$ (S from French *son*—sound) is a phonetic unit (less often a combination of phonetic units) corresponding to one or two sounds.

For example, $L_1 = S_1: \zeta = [s]; L_2 + L_3 + L_4 = S_2: eau = [o]; L_3 + L_4 = S_2: au = [o]; L_5 + L_6 = S_3 + S_4: oi = [wa]; L_2 + L_7 + L_8 = S_0: -ent$ as the ending of verbs in the 3rd person plural is not pronounced at all, i.e., S_0 is the absence of sounds.

After presenting students with one of the 48 reading rules, their understanding of it is tested. If they have not understood it, the rule is repeated in all subsequent lessons.

When modeling the didactic situation under consideration in this work, we examine a model for teaching the rules for writing and pronouncing French graphemes and their combinations, changing only the number of rules studied per week. Other parameters related to the characteristics of the teacher, teaching materials, psychological and mnemonic characteristics of students, etc., are not considered in this work. However, this variable seems to be the most important in teaching at the initial stage, since, on the one hand, without sufficiently rapid mastery of the rules of reading, it is impossible to effectively progress through the curriculum, and on the other hand, the average human memory is usually not capable of simultaneously perceiving and transferring large amounts of information into long-term memory. The hypothesis was that students at a technical university, who have a technical mindset and poorer linguistic memory than humanities students, should be taught more slowly, with the rules presented in portions. The calculations in this case were to find the optimal number

of lessons and portions of reading rules taught to first-year students at RTU MIREA. Figure 1 describes the steps involved in teaching phonetics and reading. The rule R_n (R from *règle*) is the rule number n from a list consisting of 48 rules.

Each i th lesson covers q rules and repeats $q \cdot i$ rules, except for the first lesson, where no rules are repeated, and only the first set of rules is covered. Since students only repeat what they have already learned for the rest of the semester, this formula remains in effect until all rules have been covered.

In order to determine the optimal model for teaching French letter combinations, the effects of three teaching situations were studied: intensive study of all 48 rules over four weeks, slow study over the entire semester, and study at an average pace over half the semester. The most effective model was considered to be the one for which the share of correct answers when reading French words was the highest compared to the other models.

RESULTS

Model 1. When teaching French pronunciation rules for certain combinations of graphemes, six new rules are introduced in each lesson over the course of half a semester; in the subsequent, lesson they are reviewed along with six new ones, and so on, until all the reading rules have been covered. As can be seen in Fig. 2, by the ninth lesson, i.e., after studying all 48 rules and repeating most of them, the average student has still not sufficiently mastered the rules for reading letter combinations. Each subsequent lesson increases the share of correct answers given by students when reading

words containing a particular combination of graphemes pronounced in a specific way. Thus, by the end of the semester, the success rate in mastering the rules has increased to 93%.

Model 2. During intensive training in French pronunciation rules for certain grapheme combinations, 12 new rules are taught in each lesson over the course of a quarter; in the next lesson, these are reviewed along with 12 new ones, and so on, until all the reading rules have been covered. As can be seen in Fig. 3, by the fifth lesson, the rules for reading letter combinations have been poorly mastered. Each subsequent lesson again increases the share of correct answers from students; this is due to all rules being repeated multiple times. Thus, by the end of the semester, the success rate in mastering the rules has increased to 81%.

Model 3. When teaching French pronunciation rules slowly, three new rules are introduced in each lesson throughout the semester; in the subsequent lesson, they are repeated along with three new ones, and so on, until the end of the semester. Thus, the last three rules are studied in the very last lesson of the semester, as a result of which they cannot be repeated in subsequent lessons. As can be seen from Fig. 4, by the end of the semester, despite repeated repetition of a number of rules, not all rules could be fully mastered, which led to the total number of correct answers not reaching the required level.

Thus, intensive and slow learning in a non-language university led to lower performance at the end of the

semester. Fewer students learned to read correctly than at the average learning speed, i.e., when all the rules were presented during the first half of the semester and repeated during the second half of the semester.

The proposed models illustrate average data regarding French language learning at the initial stage at RTU MIREA. However, it is important to take into account the high variability of both individual learning trajectories and the average level within a specific group, since, as experience shows, groups have different levels and characteristics. This variability is determined by a number of factors (F), including cognitive and linguistic abilities, psychological characteristics, motivational attitudes, workload, educational conditions, etc. [14]. Within the framework of constructing a prognostically correct model, students' mastery of French reading rules will be determined by the additive sum of the influence of all possible factors and the level of mastery of each specific rule. Consequently, the effectiveness indicator of the lesson (Fig. 5) is expressed in the number of correct answers recorded after mastering the reading rules, in accordance with the formula:

$$Ef = \sum_{i=1}^n F_i + \sum_{R=1}^m Z_R,$$

where F_i is one of n significant factors characterizing students' ability to master the rules of reading and pronouncing French grapheme combinations; Z_R is the accumulated knowledge of the student N regarding rules of reading (rules R from 1 to m).

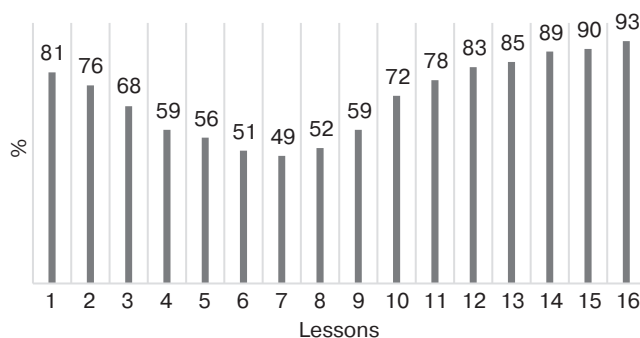


Fig. 2. Share of correct answers in lessons during the semester when studying 6 rules over 8 weeks (%)

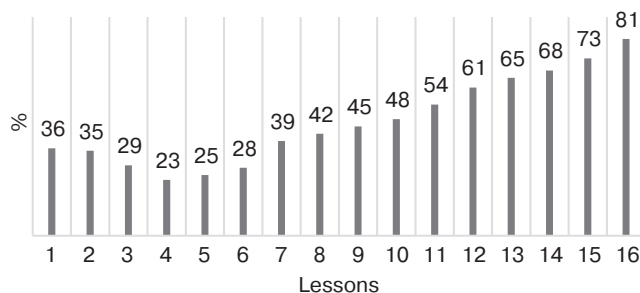


Fig. 3. Share of correct answers in lesson during the semester when studying 12 rules over 4 weeks (%)

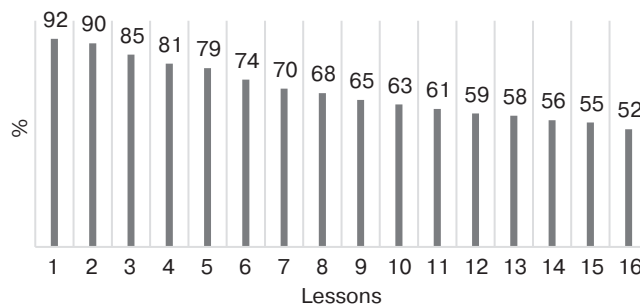


Fig. 4. Share of correct answers when studying 3 rules over 16 weeks (%)

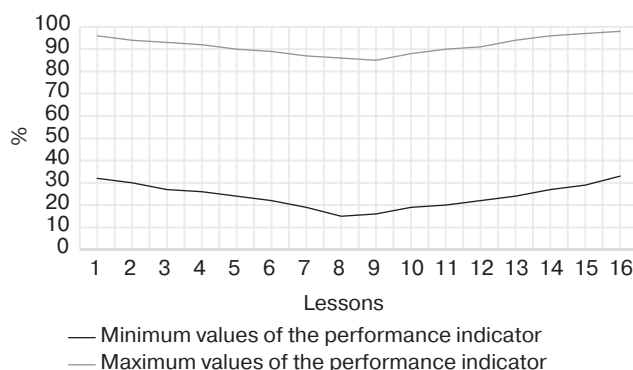


Fig. 5. Lesson effectiveness graph showing the share of correct answers over 16 weeks based on the effectiveness indicator when using Model 1

SUMMARY

The optimal approach to teaching French to beginners turned out to be a program in which reading rules are taught only in the first half of the semester and then regularly repeated in each lesson until the end. The study showed that students who studied using this model learned the material better than those who studied using the other two methods: slow learning throughout the semester and intensive learning of all the rules over four lessons.

In the first case, due to the extended study period, students did not have time to review some of the material at the end of the semester; moreover, fewer rules were reviewed in lesson. For example, Rules 1, 2, and 3 were practiced throughout the semester in all variants, while Rules 46, 47, and 48 were practiced for just over half the semester when studying the rules over 8 weeks and only during one lesson when studying the rules throughout the semester.

In the second case, intensive study led to confusion about the rules and cognitive overload, resulting in poorer memory retention [27].

Moreover, it is important to consider that various factors [28] influence the effectiveness of training, such as:

- 1) the student’s intellectual and linguistic abilities;
- 2) level of anxiety and adaptability;

- 3) speed of information perception;
- 4) motivation (internal and external);
- 5) group size;
- 6) lesson schedule;
- 7) amount of independent work;
- 8) previous language learning experience.

In the presence of unfavorable factors (poor abilities, high anxiety, etc.), learning outcomes were low regardless of the model chosen. Conversely, under favorable conditions (good abilities, motivation, etc.), the learning model does not play a decisive role.

Considering the average level of students, the eight-week model (with learning the rules in the first half of the semester and then reviewing them) proved to be the most effective, so it can be recommended for use in the educational process.

CONCLUSIONS

The theoretical and practical significance of the study lies in the solution of the tasks set and the well-reasoned conclusions based on its results:

- 1) variables for formalizing the educational process have been defined;
- 2) options for models acceptable for assessing the educational aspects of French language teaching in a technological university have been selected;

- 3) certain models describing the process of mastering the pronunciation of French letter combinations have been analyzed;
- 4) it has been shown that the optimal model for studying the pronunciation rules of French letter combinations is one in which students learn all the rules in eight lessons, with repetition in subsequent lessons.

Didactic modeling of elements of the educational process enables the optimal planning of students' educational activities, including foreign language learning. The creation of a series of models covering all potential objects, concepts, forms, characteristics, patterns, parameters, categories, and factors of learning, and the generalization of the results obtained, make it possible to modernize curricula and plans, methods, and technologies.

A promising area for further research is to study the potential of the developed methodology as a basis for the development of didactic, mathematical, and computer models for other thematic blocks of the curriculum, as well as universal, adaptive, and effective forms, methods, and technologies for teaching foreign languages in non-language educational institutions.

Authors' contributions

N.I. Chernova—justification for the study concept, developing the experimental work algorithm, research findings synthesis.

E.A. Ivanova—analysis and synthesis of the literature, study of Russian and foreign publications on the issue, drafting the manuscript.

N.V. Katakova—formulation of the conclusions, interpretation of the study results.

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