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Teaching Learners of Specialized Classes the Method of Mathematical Modeling based on Solving Problems with Practical Content

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ABSTRACT: The state of the art for research focused on the formation of mathematical thinking and analytical skills in learners revolves around several key developments and approaches in modern education, cognitive science, and instructional technology. It should also be noted that this topic is not sufficiently studied by other researchers, educators, and mathematicians. The research aims to understand how using mathematical modeling in specialized classes can make learning more effective. By focusing on real-world, practical tasks, the study seeks to show how applying math to everyday problems can deepen students' understanding and make the subject more engaging and relevant to their lives. Analysis, induction, deduction, and synthesis are the main methods of the research, allowing the description and highlighting of the most important aspects of the mathematical modeling methods application in profile classes. The article presents the following information: the study of the impact of learners' use of mathematical modeling on their understanding of the material presented; the definition of the concepts of "model" and "mathematical modeling" is given, the stages of this process are described; the application of tasks with practical content is studied; the concept of "system of tasks" and the main methods of its construction are considered; an elective course "Mathematical modeling" for learners of profile classes is proposed. The materials of the article are of practical and theoretical value for teachers, mathematicians, other representatives of the scientific community, and researchers of the topic of implementation of methods of mathematical modeling in the course of mathematics for specialized classes, interested in features and aspects of the application of tasks with practical content in the learning process, explore the role of mathematical modeling in the process of formation of mathematical thinking.

Keywords: pedagogics, school, algebra, applied tasks, task system.

I. INTRODUCTION

The primary goal of school education is to develop thinking, informed, and active people. Mathematics is the tool necessary to achieve this goal. It allows us to set and answer important social, scientific, and political questions and to analyze the claims made by politicians. J.P. Abrams [1] describes mathematical modeling as the process of using mathematics to study issues related to both mathematics and other disciplines. The methods and skills that are used to model the situation allowed us to get a simplified and structured representation of the studied object. Visualization occurs through structures such as graphs, equations, or algorithms. This representation (or model), in turn, helps to obtain new information about the object of study. Researchers argue that during such interdisciplinary research, learning mathematics is not the result of the work; rather, mathematics serves as a tool for addressing non-mathematical topics. Thus, scholars conclude that teaching learners to use mathematical methods in this way builds the skills they need to solve everyday problems. Consequently, this kind of education is much more beneficial to learners than traditional education.

Under J. Cai et al. [2], in today's dynamic digital society, mathematics is an integral and important component of research in disciplines such as biology, medicine, social sciences, business, etc. Each of these fields requires an understanding and ability for mathematical modeling, so the topic of modeling in mathematics education is given more and more time. Moreover, in many countries, mathematical modeling has been incorporated into

educational standards. Among these states are the United States, Germany, and France. Z. Kohen and D. Orenstein [3] claim that although a wide range of real-world problems can be solved using mathematics, many learners do not always see the need to apply mathematics to their everyday lives, which leads to decreased motivation during the learning process. Another problem for mathematics teachers related to lack of relevance is the mismatch between traditional teaching methods and engaging learners in applied problem-solving. The solution to these problems, from the researchers' point of view, is mathematical modeling. W.J. Meyer [4] forms a mathematical model as a model consisting of mathematical entities such as constants, variables, inequalities, functions, and equations. The researcher argues that mathematical models are in many ways superior to material models, as they allow easy changes in their structure, which contributes to a more qualitative study. W. Blum [5] suggests the following steps in the process of mathematical modeling (Table 1).

Table 1. The process of mathematical modeling.

Step	Description
1. Model Creation	Formulating a mathematical representation of a real-world problem.
2. Simplification	Reducing the complexity of the model by making assumptions or approximations.
3. Calculations	Performing mathematical operations and computations based on the model.
4. Interpretation	Translating the mathematical results back into the context of the real world.
5. Proofing	Verifying the correctness and accuracy of the model and calculations.
6. Revealing	Identifying deeper insights or conclusions drawn from the model's results.

Following these, W. Blum [5] defines a person's skill in mathematical modeling as the ability to create and use mathematical models, perform steps according to the problem, and analyze or compare model data.N. Shapovalova and L. Panchenko [6] believe that the introduction of applied orientation in the process of learning mathematics in specialized classes means (Table 2):

Table 2. The process of learning mathematics in specialized classes.

Step	Description
1. Creation of Mathematical Models	Developing multiple mathematical models that describe real-world phenomena and culturally significant processes.
2. Formation of Knowledge and Skills	Providing students with the theoretical knowledge and practical skills required to understand and study these models.
3. Teaching Independent Model Building	Enabling students to independently construct and explore simple mathematical models.

The relevance of the stated problem is defined by the need to form learners' mathematical thinking and analytical skills, which will allow them to solve various problems throughout their lives.

As a result, the research aims to address the challenge of teaching learners in specialized classes the method of mathematical modeling, particularly by solving practical problems. It underscores the importance of applied tasks to enhance students' engagement and understanding, promoting the development of both theoretical knowledge and practical skills required for independent problem-solving.

II. MATERIALS AND METHODS

Throughout the study, the following methods were used: theoretical methods (study and analysis of pedagogical and mathematical literature and articles on the use of methods of mathematical modeling in the profile classes); analysis of the application of tasks with practical content, their impact on the learners' understanding of the material; generalization of theoretical material on the issue under study; deduction in comparing approaches and materials to study methods of implementing mathematical modeling in the course of mathematics profile classes; classification of positive aspects of using the mentioned methods in teaching; diagnostic (study of resources in curricula, questionnaires, and interviews with learners); empirical (observation

of the level of understanding of the material and interest in it among learners); teaching experiment in natural conditions (study of the level of perception of information in the classroom); methods of graphic representation of results.

The experimental basis of the research was N. Ondasynov School-Gymnasium No. 38, a Specialized Boarding School No. 2 with Three Languages of Education, as well as students of M. Auezov South Kazakhstan University. The sample consisted of 60 pupils and 140 students. (60 pupils in specialized classes and 140 students studying "Higher Mathematics" discipline) (Table 3).

Table 3. Stages of Research on Mathematical Modeling in Specialized Classes

Stage	Description
1. Theoretical Analysis	- Collected and analyzed existing approaches in pedagogy, mathematics, and psychology related to the use of mathematical modeling in teaching. - Reviewed scientific works (books, educational programs, dissertations, articles, monographs, conferences) on the impact of applied tasks on learners' understanding. - Highlighted the problem, purpose, forms, and methods of research. - Developed a plan for experimental research.
2. Practical Study & Experimentation	- Investigated the impact of mathematical modeling on learners' understanding in specialized classes. - Considered stages of mathematical modeling and principles of using tasks with practical content. - Explored the concept of a "task system" and methods for its construction. - Analyzed learners' understanding in Kazakhstan using mathematical modeling methods. - Suggested an elective course "Mathematical Modeling" aimed at developing analytical skills. - Systematized experimental conclusions.
3. Systematization & Analysis	- Systematized and classified the research findings on practical task usage in math teaching. - Conducted a comparative analysis of studies and experimental approaches of scientists, teachers, and psychologists. - Summarized other educators' experiments on implementing mathematical modeling methods. - Analyzed and substantiated the relevance of mathematical modeling in specialized classes. - Presented final theoretical and practical conclusions.

III. RESULTS

Mathematical modeling and its stages. Discussing the use of mathematical modeling techniques in teaching, it is important to understand the definitions of "model" and "mathematical modeling". A model is a simplified abstraction or material system created to represent a real-world object. Models are used in research because they can replace a real-world object to obtain new information about it. Mathematical modeling, in turn, is an ideal scientific character formal modeling, in which the description of the object is carried out in the language of mathematics, and the study of the model is carried out with the use of certain mathematical methods [7]. There is no clear consensus in the scientific community on the formulation of the stages of mathematical modeling. Nevertheless, in general terms, this process is carried out by Table 4 [8].

Table 4. The stages of mathematical modeling.

Stage	Description
1. Problem Formulation	Clearly define the objective of the model. The model's purpose and the study's goals determine the type of model to be created.
2. Model Creation	Develop an algorithm that enables the model to function. Input and output data are defined, and the relationships between these data are established.
3. Model Analysis	Assess whether the developed model aligns with the problem. If it does not meet the requirements, modifications to the model or even the problem itself may be necessary.

4. Model Testing	Solve the model numerically. This stage produces the data required for interpreting the model's outcomes.
5. Model Interpretation	Compare the obtained results with experimental data. Evaluate the consistency of the results with reality and the characteristics of the object being modeled.
6. Model Optimization	Review the structure and results of the model to identify improvements. This step seeks to enhance the quality and accuracy of the model's output.

It is also worth noting that mathematical modeling methods are used everywhere in many branches of science. For example, using mathematical modeling methods, a study was conducted in which the dynamics of the spread of coronavirus infection in India was studied qualitatively and appropriate solutions were developed to counteract the further spread of the disease [9].

Practical tasks. The core of the practical orientation of learning mathematics is the focus on the objectives, content, means, methods, and organizational forms of learning to form learners' abilities and skills to solve mathematical problems. Besides the practical orientation of the school mathematics course, mathematicians often discuss the applied orientation of mathematics education. It consists of the orientation of the goals, content, and means of mathematics teaching in the direction: providing purposeful meaningful and methodological links between mathematics and practice; acquisition of knowledge, skills, and abilities by learners in the process of mathematical modeling, which will be used by them in everyday life, education, and future professional activities.

The practical tasks play a crucial role in enhancing and intensifying the process by which learners develop the ability to apply mathematical knowledge in practical, non-standard situations. These tasks allow students to effectively use the knowledge they acquire not only within mathematics but also across other disciplines, fostering interdisciplinary connections. Moreover, practical tasks contribute to improving students' overall practical training in mathematics, equipping them with skills that are applicable in real-world contexts. Additionally, they help form a scientific understanding of the world, increasing learners' motivation to engage in the learning process and fostering a deeper appreciation for the subject [10].

Regarding tasks with practical content, it is worth paying attention to the concept of "systems of tasks", which is one of the key concepts in teaching mathematics. The system of tasks is a set of all the tasks solved during the course. They should be interconnected, complement each other, and correspond to the studied topic. The system of tasks expedites the formation of a comprehensive and complete understanding of the concepts considered in the block of lessons. The main requirements for the task system include the need for tasks that are closely related to each concept within the topic being studied. Additionally, tasks should be interconnected, with solutions of one task aiding in the understanding or solution of others. There should also be a sequential increase in the difficulty of tasks, ensuring that learners progressively build their skills. Finally, the task system must provide an optimal number of tasks to thoroughly cover and fully disclose the topic at hand [12].

Mathematic modeling methods in profile classes. The main results of the study consist in identifying the success of the study of mathematical modeling methods by learners of the profile classes based on tasks with practical content. The research was conducted based on N. OndasynovSchool-Gymnasium No. 38, a Specialized Boarding School No. 2 with Three Languages of Education, as well as M. Auezov South Kazakhstan University students. The participants were 10th-grade learners in the profile classes and first-year students studying the "Higher Mathematics" discipline. The sample consisted of 60 pupils and 140 students. The results were determined based on a natural experiment (observation of the learning process) and a questionnaire concerning the level of understanding of the material while learning.

The observation method was used to study the process of using methods of mathematical modeling in the teaching of mathematics in specialized classes. The results of the study were obtained through the use of tasks with practical content. The main criteria of observation included: the degree of mastering the skills of using mathematical models to analyze and solve educational and cognitive tasks; the level of knowledge and the coefficient of completeness of assimilation of the obtained educational information. During the work with practical tasks, the learners showed a high level of motivation for learning, as well as a high level of understanding of the material as real-life applications of mathematics, contribute to the understanding of the material presented. The learners showed more interest in the subject, asked more questions, participated more actively in the lesson, etc. The use of methods of mathematical modeling also helped to simplify the process of solving problems and allowed us to develop learners' analytical skills. The statistical results of the research are presented in the diagram (Figure 1).

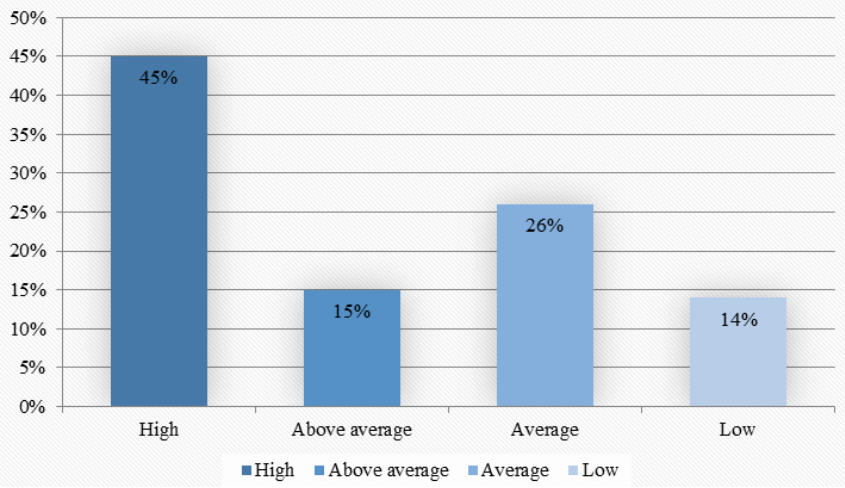

FIGURE 1. The level of learning of the material by learners when working with methods of mathematical modeling

Based on the results of the questionnaire, it can be concluded that 90 learners showed a high level of understanding of the material, 30 – above average, 52 – average, and 28 – low. Consequently, it can be concluded that the use of mathematical modeling methods when working with tasks with practical content, contributes to an increase in the level of understanding of the material by learners of specialized classes. Based on the results of the study, an elective course "Mathematical Modeling" for the specialized classes was suggested. The elective course aims to study the modern methods of mathematical modeling and ways of their use in solving problems with practical content.

The objectives of the elective course are to introduce learners in specialized classes to the principles, methods, and possibilities of mathematical modeling, along with its theoretical foundations as a scientific method. The course aims to develop an understanding of the key problems addressed by mathematical modeling and the conditions under which mathematical methods can be applied to formalize economic and physical processes. Additionally, the course seeks to cultivate practical skills in learners, enabling them to independently create, solve, and draw conclusions from mathematical models.

The primary blocks and topics of the elective course include an exploration of the concepts of "model" and "mathematical modeling," as well as practical tasks related to the topics of "Derivative" and "Definite Integral." These components are designed to provide a comprehensive foundation in mathematical modeling and its applications.

The main purpose of teaching mathematics in science and mathematics classes is to form learners' mathematical thinking. One of the important features of this thinking method is, for example, the use of rational reasoning. Such reasoning schematizes and idealizes reality less than the deductive inferences of pure mathematics, hence it is more suitable for analyzing real facts and processes, for solving technical, chemical, agricultural, ecological, and similar problems.

Mathematical thinking enables learners to develop several crucial skills. It empowers them to model real processes by building mathematical models that accurately represent these processes. Additionally, it equips them with the ability to conduct experimental research correctly, ensuring that their investigations are methodologically sound. Learners also gain the competency to evaluate the results of measurements and calculations effectively, ensuring accuracy and reliability in their findings. Furthermore, mathematical thinking helps learners choose the appropriate algorithm or mathematical method for solving specific problems, allowing them to approach challenges with the right tools and techniques [13].

The use of the considered mathematical modeling methods and the use of tasks with practical content in the study of algebra and the beginnings of analysis, in particular when considering the topics of the derivative and definite integral is especially important. It should be noted that the course "Algebra and Analysis Basics" provides a basis for the study of "Higher Mathematics" and "Mathematical Analysis" in universities, the main feature of which is a practical orientation. Further study and perception of the links between mathematics and other branches of science depend on the successful mastering of the basic concepts of analysis at school. Following the curriculum, the basic concepts of mathematical analysis such as "limit", "derivative" and "integral" are introduced

in the upper grades of secondary schools. One of the main problems in the study of this material is its excessive abstraction, which complicates the perception of key concepts and reduces the interest of learners [14].

As for the concept of the derivative or integral, it is worth noting that most learners have difficulty understanding these concepts. For example, they can give correct definitions of these concepts, but they can hardly name a single way of the practical application of these mathematical methods. It is assumed that the use of tasks with practical content may allow learners to better understand the topic. For example, when reviewing the topic "Integral" with learners, it is worth paying more attention to problems of finding the area of simple and complex geometric shapes. It will also be useful to consider problems related to economics, such as problems with a continuous source of income. Regarding the topic "Derivative", learners should pay attention to the possibilities of application of the derivative in various fields of science, for example: in geometry, the derivative characterizes the steepness of a graph, in mechanics – finding the speed of an irregular rectilinear motion in mechanisms, the rate of reproduction of microorganisms in biology, the rate of chemical reactions in chemistry, or determining the amount of product produced per unit cost in economics.

IV. DISCUSSION

Before comparing the conclusions of this study with those of other scientists, it is necessary to briefly outline the results of this work. The definition of "mathematical modeling" and the stages of implementation of this process were defined. The issue of applying tasks with practical content in the study of mathematics in the profile classes was considered. The formation of mathematical thinking in learners in the process of studying methods of mathematical modeling, which contributes to the development of analytical, and critical skills, etc. was also investigated. It was noted that the application of methods of mathematical modeling in the profile classes positively affects the level of understanding of the presented material. In general, the suggested interpretation of the presented results can become the basis for a new hypothesis or theory within this and other directions. Considering the practical importance of mathematical modeling research, it is worth highlighting its social and cultural functions. C. Bonotto [15] views modeling as a means by which learners develop an understanding of mathematics as an important social tool. It allows them to analyze and understand the communities in which they function or society as a whole. The scientist believes that an important task of educational standards should be to teach learners critical thinking, through which they can adequately perceive the surrounding reality and understand its norms and rules. Based on this, it can be said that C. Bonotto considers mathematical modeling from a point of view different from the one proposed in this paper. Nevertheless, his conclusions are a qualitative addition to the final results of this study.

Considering the importance of applying mathematical modeling methods, it will be useful to consider the work of D. Karali and S. Durmuş [16], in which researchers considered the value of mathematical modeling methods in learning mathematics. It notes that solving text problems can be effective for acquiring basic skills (basic mathematical operations) but does not allow the perception of more complex mathematical concepts and concepts. Researchers believe that traditional text problems do not intersect with real-world examples, do not develop problem-solving skills, and do not contribute to the proper evaluation of mathematical models. The authors argue that traditional text or algebraic problems do not require learners to think deeply mathematically. By contrast, mathematical modeling involves transferring real-world situations into a model, which is then used to better understand, construct, and solve real-world problems. Thus, the conclusions about the importance of learners learning mathematical modeling methods agree with the final results of the researchers' work.

Discussing the advantages of modeling over traditional approaches in teaching mathematics, it will be useful to examine the work of B. Riyanto et al. [17]. In it, they outlined the main differences between the traditional approach and mathematical modeling methods. The researchers argue that the use of modeling in teaching makes mathematics more understandable and interesting for learners. According to the authors, traditional teaching is insufficient to prepare 21st-century learners, and separating learning from problem-solving is fundamentally flawed. In the traditional approach to learning, learners are focused on achievement rather than understanding the concepts and processes they are learning. An equally important negative tendency is that learners are required to give correct answers validated by the teacher. They are considered successful if their actions coincide with the teacher's expectations. Researchers conclude that quality training of learners in the accelerated development of information technology can be achieved with the help of mathematical modeling, as it allows you to apply the acquired skills in real-world tasks. Consequently, the conclusions of the researchers agree with the conclusions reached in this work.

As the research issue considers teaching mathematical modeling methods to learners of profile classes, it will be appropriate to consider the work of A. Arseven [18]. In this work the researcher reveals the problem of mathematical modeling methods teaching, and also offers several forms of presentation of the material. First of

all, it is necessary to compose classes so that learners deeply and comprehensively understand the material and tasks, and come to the necessary conclusions, by expressing assumptions. It is also important to understand that teaching material using mathematical modeling techniques is unfamiliar to most mathematics teachers.

In this regard, R.M. Zbiek et al. suggest that teachers need to develop new skills for effective presentation. One important skill is to encourage learners to arrive at correct answers by guiding them in developing their own assumptions. Instead of simply accepting or rejecting answers, teachers should demonstrate their validity through practical application. Additionally, teachers should focus on fostering teamwork skills among learners. This involves helping students collaborate and support each other in overcoming challenges while learning new material. These approaches aim to enhance both individual understanding and collective learning.

In these articles, researchers reveal aspects of mathematical modeling teaching methods not covered in this study, so they can be useful in a more in-depth study of the problem. In modern conditions, it is also important to remember the necessity of using multimedia and information technology. This topic was qualitatively researched by S.T. Turdaxunova [21]. In her work, she argues that the effective use of computer technology is a key factor in the modernization of modern education. Modern technologies allow for qualitative diversification of the study of mathematics. Thus, using presentations, animations, and videos the teacher can present new material in a more comprehensible way. For example, the use of presentations significantly reduces the time needed to explain the material. Through the use of information technology during classes, the teacher has the opportunity to show the necessary tables, graphs, charts, animations of mathematical processes, visual models, photographs, etc. The scientist argues that the use of all kinds of information resources in the educational process significantly increases the quality of teaching material, as well as the level of its perception and assimilation by learners. Thus, the materials of this article, although they rock the given topic indirectly, are a qualitative addition to the study of methods of teaching mathematics in specialized classes.

When considering the problem of using tasks with practical content, it is necessary to refer to the works of Y. Song and P. Ji [22]. They believe that the key skill obtained by learners in the study of mathematics is the ability to find the relationship between theoretical knowledge of mathematics and practical tasks arising in life. Following researchers, solving practical tasks in educational institutions allows you to learn how to effectively solve the tasks, using methods of analysis, synthesis, as well as mathematical knowledge learned earlier. Moreover, M. Artigue [23] believes that in the process of solving practical problems learners become convinced of the importance and practical value of learning mathematics. Consequently, the conclusions about the importance of applying tasks with practical content are supported by the conclusions reached by the mentioned researchers.

Considering the purpose of creating profile classes, as well as the use of practical tasks during the study of mathematics in them, it is worth studying the article by L.O. Sokolenko [24]" On the necessity of creating of a system of applied sciences problems for the profile teaching of mathematics". The author states that the main purpose of education is to provide society with professionally trained specialists. Based on this principle it is necessary to conduct profile differentiation in the study of mathematics and other disciplines. According to the scientist, achieving a greater effect from the allocation of profile mathematics classes is possible through the development of a special system of tasks aimed at the applied study of natural sciences.

Following the point of view of Y. Song [25], the profile study of mathematics is a necessary condition for the full mastery of the skills necessary for further training in technical specialties. In the context of the modernization of education, he suggests using modern information technology to improve the perception of the material instead of traditional methods of presenting information that is usual for both learners and teachers. It also greatly optimizes the process of learning mathematics and develops forms of information exchange between teachers and learners. The scientist believes that conducting practical classes in specialized classes overcomes the difficulties learners encounter in the process of learning mathematics, stimulates interest in learning the material, and increases the level of development of such qualities of learners as the ability to learn more effectively; the ability to analytically evaluate the material; the ability to solve practical problems in everyday life.

V. CONCLUSION

The research paper outlines the concept of "mathematical modeling" and describes its various stages. It identifies practical problems designed to improve learner success and examines the role of a task system in teaching mathematics, including methods for its development. Additionally, the article discusses mathematical thinking and its associated skills, such as solving applied problems, constructing mathematical models, and conducting experimental research, which are essential for mastering mathematical concepts. An empirical study was conducted to determine the impact of using methods of mathematical modeling on learners' understanding of the material provided. The problems encountered by learners during the study of such topics as the derivative

and integrals were disclosed. The elective course "Mathematical modeling" for profile classes was also offered, aimed at acquainting learners with the principles, methods, and possibilities of mathematical modeling, and its theoretical foundations as a scientific method.

The materials presented in the research can be useful and relevant for teachers, mathematicians, and scientists engaged in research on the use of methods of mathematical modeling to increase the level of understanding of the material by learners of specialized classes. Also, these articles will be valuable for specialists in the field of psychology, learners, and researchers who are interested in the application of tasks with practical content in the study of algebra and the beginnings of analysis. The research should be continued and conducted in more detail, to extend the study of the process of forming systems of tasks. The carried-out research does not cover all the features of this pedagogical problem and requires further consideration of such issues as the use of applied tasks in the consideration of topics related to the derivative and integrals.

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Author contribution

All authors made an equal contribution to the development and planning of the study.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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