The constructivist approach as a concept of active learning and teaching of optimization processes at technical universities

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Abstract: As we move toward a more competitive global economy, the demand for highly qualified people to create and manage more efficient logistics systems, such as flows and management of materials or information, human flows, and supply chains, increases. Without logistics, the commercial world would grind to a halt. Businesses depend on logistics professionals to keep production and delivery moving forward which makes logistics education crucial. Companies expect their future employees to gain practical information, and to master what they are learning. Students must know how to apply what they learn. This is a reason why increasing importance is attributed to the constructivist approach to teaching and learning in university education. Through experiments or simulation of processes, and group work based on previous experience and knowledge, students better uncover the laws of phenomena. By actively engaging in the learning process, deeper and long-term applicable knowledge about the studied processes is acquired. The goal of this article is to implement the constructivist approach in the education of operational research and logistics at technical universities.

1 Introduction

The constructivist approach to learning and teaching has recently become very popular in school education. The idea that knowledge is a human construction supported by experience, first stated by Vico in the 18th century and further extended by Kant, greatly affected the epistemology of Piaget, who is considered to be the forerunner of the constructivism theory for the process of learning. This theory was formally introduced by von Glasersfeld who developed his ideas in the Piaget Foundation of the United States in 1975 [1].

According to the constructivist view, knowledge is not passively received from the environment but actively constructed by synthesizing past knowledge and experience with new information. The “coming to know” is a process of adaptation based on and constantly modified by the individual’s experience of the world [1-3].

In recent years, constructivism approach has gained popularity in teaching and learning of mathematics in primary and secondary education. However, in tertiary education, it seems that most teachers still prefer the traditional way of delivering explicit mathematics instruction. While processes studied in primary and secondary schools are relatively simple, problems tackled at the university level are more complex, time-consuming, and often span across various branches of knowledge. Therefore, incorporating constructivist approach to solving such tasks is significantly more challenging. Nevertheless, universities need to integrate such working methods into the educational process so that students are compelled to contemplate the causal relationships of processes and actively seek problem-solving strategies [4,5]. Actively solved tasks urge students not to rely on algorithmic solutions but encourage them to think about the factors influencing the course of processes, develop the ability to choose suitable problem-solving methods, work in groups, listen to others, and effectively present and defend their opinions [6,7]. Students educated in this manner subsequently achieve better results in their studies and practice [5,8]. Moreover, an increasing number of students in primary and secondary schools are being educated using constructivist methods, therefore universities should be prepared for these students.

Mathematics has been recognised as a subject that enhances higher order skills because on the one hand, it requires abstract thinking, and on the other, promotes use and application of knowledge [9,10]. At first, it is essential to identify an area of mathematics suitable for a constructivist teaching approach. One excellent area is operational research and logistics, specifically optimization problem-solving. Nowadays, each modern technical expert is required to have some awareness and sensitivity to the logistical flow of materials and information during the production process [11,12]. In the field of process optimization, a significant number of modified problem-solving methods have been developed. These methods are mostly iterative, generating a sequence of solutions in which each subsequent solution achieves a better value in terms of optimizing the process. Graphical and simplex methods are fundamental methods among the approaches to solving optimization problems in standard form with two decision variables [13]. Naturally, it is possible to use appropriate mathematical software to solve optimization problems, but we recommend to introduce this tool only after students have mastered and understood the principles of solving such problems. Software tools are suitable for solving other types of optimization problems that involve a larger number of variables, constraints, or problems not in standard form, and allow us to find solutions to solved problems quickly. However, without an
understanding of the essence of problem-solving, progress in exploring new methods and approaches to solving optimization problems can not be made.

A new interesting approach to solving optimization problems is combining both fundamental methods simultaneously. That enables students to observe the sequence of problem-solving steps, not only from an algorithmic perspective but also to perceive the graphical significance of these steps, which, in turn, helps them understand the logical coherence of the algorithm steps. Therefore, students are encouraged to consider and find connections that are often overlooked in algorithmic problem-solving. In the presented preparatory phase, the step-by-step solution of the chosen problem is linked with challenging questions and discussion with students to support critical analysis of the mathematical content. Working in groups is recommended, and students’ ideas are continuously presented.

2 Linear programming problem

Let's consider a linear programming problem (LPP) in the standard form. That means, 

Let's maximize the objective function (1)

$z(x_1, x_2, ..., x_n) = \sum_{j=1}^{n} c_j x_j,$  

subject to (2)

$\sum_{j=1}^{n} a_{ij} x_j \leq b_i,$  

for $b_i > 0, \ i = 1, 2, ..., m, \ j = 1, 2, ..., n.$

Let's choose a specific linear programming problem and demonstrate the proposed working method with students. The solved LPP is as follows:

The firm produced two kinds of products $P_1$ and $P_2$. The production is limited by the quantity of resources $S_1$ and $S_2$ and machines’ capacity $M$ per month. There are 1800 units of resource $S_1$ and 1600 units of resource $S_2$ per month. Machines $M$ are capable of being operated for at most 860 hours per month. Each piece of product $P_1$ requires 6 units of resource $S_1$ and 1 unit of resource $S_2$. Each piece of the product $P_2$ requires 3 units of resource $S_1$ and 4 units of resource $S_2$. Both products $P_1$ and $P_2$ require 2 hours of processing time on machines $M$. On each sale, the firm makes a profit of 3€ per piece of product $P_1$ sold and 4€ per piece of product $P_2$ sold. How many of each type of products should be produced to maximize the total monthly profit?

2.1 Mathematical formulation of LPP

At first, the solved linear programming problem is mathematically formulated. This step might be demanding for students. They need to realize the desired relationships between variables and recognize technological parameters with their impact on maximizing the objective. Therefore, creating more mathematical models of optimization problems with students is highly recommended.

How can the provided information be structured clearly? Creating a table of given data helps to organize and structure the provided information and leads to a better understanding of the mathematical model construction process. The input data of the solved problem can be written in the form of the following table, Table 1.

<table>
<thead>
<tr>
<th>Resource $S_1$</th>
<th>$6$</th>
<th>$3$</th>
<th>$1800$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource $S_2$</td>
<td>$1$</td>
<td>$4$</td>
<td>$1600$</td>
</tr>
<tr>
<td>Machines $M$</td>
<td>$2$</td>
<td>$2$</td>
<td>$860$</td>
</tr>
<tr>
<td>Profit</td>
<td>$3$</td>
<td>$4$</td>
<td></td>
</tr>
</tbody>
</table>

According to a standard form of LPP and Table 1, the mathematical formulation of the solved LPP has the following form:

Let’s find the values of two variables, $x_1$ and $x_2$, such that they maximize the objective function

$z(x_1, x_2) = 3x_1 + 4x_2,$

subject to the following constraints (3)

$6x_1 + 3x_2 \leq 1800,$  

$x_1 + 4x_2 \leq 1600,$

$2x_1 + 2x_2 \leq 860,$

$x_1 \geq 0,$

$x_2 \geq 0.$

2.2 A constructivist approach to solving LPP

The optimal solution to the solved problem can be found by the graphical method [13]. How can a mathematical model be graphically represented? At first, let’s plot all inequalities (3) on a graph on the $x_1$x_2-coordinate plane. How can the inequalities $x_1 \geq 0$ and $x_2 \geq 0$ be graphically interpreted? Since the two decision variables $x_1$ and $x_2$ are non-negative, let’s consider only the first quadrant of the $x_1$x_2-coordinate plane. What do the other constraints graphically mean? Graphing each constraint, a half-plane is obtained. The first constraint in the first quadrant is represented by a region (Figure 1).
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The feasible region is just the intersection of three half-planes in the first quadrant (Figure 2).

The coordinates of vertex C represent the optimal solution of the given maximization problem, \( x_1 = 40 \), \( x_2 = 390 \), and \( z(C) = 1680 \) is a maximum value, the highest obtained profit of the firm under given circumstances.

Let’s analyze determining the optimal solution to the same problem step by step to understand the meaning of performed steps and look for connections in the procedure of solving the task with a graphical solution. Simultaneously, let’s look at calculating the solution to the task using the simplex method [13].

The objective function can be written in the equivalent form

\[
-3x_1 - 4x_2 - 0s_1 - 0s_2 - 0s_3 + z = 0.
\]

Therefore, the initial tableau of the simplex method is as follows, see Table 2.

### Table 2 Initial tableau of the simplex method

<table>
<thead>
<tr>
<th>Base</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
<th>( s_1 )</th>
<th>( s_2 )</th>
<th>( s_3 )</th>
<th>( z )</th>
<th>( b_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s_1 )</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1800</td>
</tr>
<tr>
<td>( s_2 )</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1600</td>
</tr>
<tr>
<td>( s_3 )</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>860</td>
</tr>
<tr>
<td>( z )</td>
<td>-3</td>
<td>-4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

How many solutions have systems of linear equations (4)? The system of three constraint equations contains five unknowns. From linear algebra, we know that such a system has infinitely many solutions. **How can solutions be determined?** These solutions can be obtained by arbitrarily choosing the values of two variables and calculating the values of the remaining three variables from the given system of equations (4). Since each slack variable \( s_i \), \( i = 1, 2, 3 \) appears in exactly one equation, the process of expressing it will be straightforward. After some manipulations, we obtain

\[
\begin{align*}
\text{(5)}
\end{align*}
\]

\[
\begin{align*}
\begin{align*}
\text{(5)}
\end{align*}
\]

\[
\begin{align*}
\text{(5)}
\end{align*}
\]
The values of variables $s_1, s_2,$ and $s_3$ can be obtained by choosing the values $x_1 = 0$, and $x_2 = 0$. Then, by (5), $s_1 = 1800, s_2 = 1600, s_3 = 860$. This allows us to determine the first basic feasible solution. **What does the initial basic feasible solution mean?** At first, let’s consider a production plan where no products $P_1$ and $P_2$ are manufactured ($x_1 = 0, x_2 = 0$). In that case, the inventory levels of resources $S_1$ and $S_2$, as well as the available machines’ hours $M$, remain unchanged, remaining in their original quantities (there are 1800 units of resource $S_1$ in stock, 1600 units of resource $S_2$, and 860 available machines’ hours, $s_1 = 1800, s_2 = 1600, s_3 = 860$). **What is the graphical interpretation of the initial basic feasible solution?** The initial solution graphically corresponds to vertex $O=[0;0]$ of the feasible region (Figure 3).

![Figure 3 Initial basic feasible solution](image)

**What is the value of the objective function for the initial solution?** Is it possible to increase this value by modifying the production plan (using a different feasible basic solution)? Is the obtained initial solution optimal? **What is the meaning of the coefficients of the objective function?** To determine whether the obtained solution is optimal, it is necessary to assess if the value of the objective function $z(x_1, x_2) = 3x_1 + 4x_2 = 0€$ is maximized. Let’s analyze the objective function $z = 3x_1 + 4x_2$. The coefficients of the function are non-negative, where one unit of product $P_1$ yields a profit of 3€ and one unit of product $P_2$ yields a profit of 4€ to the firm. Therefore, it is necessary to modify the production plan by introducing either product $P_1$ or product $P_2$ to increase the firm’s profit (the value of the objective function). **Which product, not currently in the production plan, will yield a higher increase in profit?** By comparing the positive coefficients of the objective function (the unit profit from producing products $P_1$ and $P_2$), it was found that introducing the production of product $P_2$ will be more advantageous in terms of maximizing profit.

**How many products $P_2$ can be produced with the available quantity of resources and machines’ capacity?** Let’s examine each resource individually. There are 1800 units of resource $S_1$ in stock, and producing one piece of product $P_2$ requires 3 units of resource $S_1$. Therefore, 1800/3=600 pieces of product $P_2$ can be produced by using the available quantity of resource $S_1$. As for resource $S_2$, 1600/4=400 pieces of product $P_2$ can be made. The machines’ hours $M$ allows to produce 860/2=430 pieces of product $P_2$. The resource limiting production the most is the quantity of resource $S_2$, which determines that a maximum of 400 pieces of product $P_2$ can be produced.

**How can the amount of manufactured product $P_2$ be expressed?** Resource $S_2$ will be completely depleted, and thus the second inequality in the system (3) will be satisfied as an equation. The vector corresponding to the leaving variable $s_2$ will be replaced by the vector corresponding to the entering variable $x_2$ in the new production plan. Therefore, for the new basic variable $x_2$, the following condition holds

$$x_1 + 4x_2 + s_2 = 1600,$$

$$x_2 = 400 - \frac{1}{4}x_1 - \frac{1}{4}s_2.$$  \hspace{1cm} (6)

**How do the inventory of resource $S_1$ and machines’ capacity $M$ change through the production of product $P_2$?** Since the production of product $P_2$ requires not only resource $S_2$ but also consumes resource $S_1$ and machines’ hours $M$, the values of the remaining basic variables $s_1$ and $s_3$ are modified accordingly. Therefore, using equations (5) and (6), we obtain

$$s_1 = 1800 - 6x_1 - 3(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2),$$

$$s_1 = 600 - \frac{21}{4}x_1 + \frac{3}{4}s_2,$$  \hspace{1cm} (7)

$$s_3 = 860 - 2x_2 - 2(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2),$$

$$s_3 = 60 - \frac{3}{2}x_1 + \frac{1}{2}s_2.$$  \hspace{1cm} (8)

**How can the current production plan be determined?** **How is the solution of a transformed system of linear equations acquired?** Since the vectors corresponding to variables $x_1$ and $s_2$ are not in the basis (not included in the production plan), their values are chosen to be zero (no production of product $P_1$, and complete depletion of resource $S_2$). Therefore, the obtained values of the basic variables are as follows: $x_2 = 400, s_1 = 600, s_3 = 60$. Hence, when producing 400 pieces of product $P_2$, resource $S_2$ will be completely depleted. Resource $S_1$ will be consumed, leaving 600 unused units in stock. The remaining available machines’ hours will be 60.

**What is the graphical interpretation of the obtained solution?** The entering base variable determines the direction of the displacement towards a new vertex of the feasible region. As $x_2$ is the entering variable, the
displacement is carried out by the OD-edge to reach the D-vertex (Figure 4).

![Figure 4 A new basic feasible solution](image)

**How will the profit be changed for the current production plan?** Since the objective function obtains the form

\[ z = 3x_1 + 4 \left(400 - \frac{1}{4}x_1 - \frac{1}{4}s_2\right), \]
\[ z = 1600 + 2x_1 - s_2, \tag{9} \]

for \( x_1 = 0, s_2 = 0 \) (non-basic variables), the total profit will be \( z = 1600€ \).

By the simplex method [13], the initial tableau Table 2 is changed into Table 3, which is in accordance with the obtained relations (6), (7), (8), and (9).

**Table 3 The second tableau of the simplex method**

<table>
<thead>
<tr>
<th>Base</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
<th>( s_1 )</th>
<th>( s_2 )</th>
<th>( s_3 )</th>
<th>( z )</th>
<th>( b_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s_1 )</td>
<td>( \frac{21}{4} )</td>
<td>0</td>
<td>1</td>
<td>( -\frac{3}{4} )</td>
<td>0</td>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>( x_2 )</td>
<td>( \frac{1}{4} )</td>
<td>1</td>
<td>0</td>
<td>( \frac{1}{4} )</td>
<td>0</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>( s_3 )</td>
<td>( \frac{3}{2} )</td>
<td>0</td>
<td>0</td>
<td>( -\frac{1}{2} )</td>
<td>1</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>( z )</td>
<td>-2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1600</td>
</tr>
</tbody>
</table>

**Does the obtained solution optimize the objective function? Is profit 1600€ maximal? How does the profit corresponding to basic variables change?** From the expression of the objective function (9), the modified profit for product \( P_1 \) and resource \( S_2 \) can also be determined. By introducing product \( P_1 \) into production and selling one unit of product \( P_1 \), the profit would increase by 2€. Including the vector corresponding to variable \( s_2 \) into the basis (to avoid completely depleting resource \( S_2 \)), the value of the objective function would decrease by 1€. Since there is still a positive coefficient in the modified objective function, the obtained solution is not yet optimal. What non-basic variable should enter the basis to maximize the obtained profit? By changing the production plan, introducing product \( P_1 \) into production, the firm’s profit can increase.

**Why is a unit profit of non-basic variables changed?** Interestingly, the original unit profit for product \( P_1 \) was 3€, but in the modified objective function it is 2€. This is due to the effect of changing the use of resources. The decrease is caused by the fact that when producing one unit of product \( P_1 \), the production quantity of \( P_2 \) products has to be reduced (due to insufficient capacity of resource \( S_2 \)). Producing one unit of product \( P_1 \) consumes 1 unit of resource \( S_2 \), which is then missing in the production of \( P_2 \) products, and thus the number of products with a profit of 4€ needs to be reduced. To produce one unit of product \( P_2 \), 4 units of resource \( S_2 \) are needed. Therefore, the production of product \( P_2 \) needs to be reduced by 1/4 unit for each unit of product \( P_1 \) produced. The modified unit profit from one unit of \( P_1 \) is reduced by 1/4 of the profit from one unit of product \( P_2 \), which is \( 3 - \frac{1}{4} \cdot 4 = 2€ \).

**How does the basis change? What will be the new production plan of the firm?** By entering the vector corresponding to variable \( x_1 \) into the basis, which increases the value of the objective function, one vector corresponding to the existing variable leaves the basis. **How can the resource which limits the production of product \( P_1 \) the most be determined? What resource will also be completely depleted by new production?** The resource which limited the production of product \( P_1 \) the most is determined by calculating the ratios of modified available resources to positive modified technological coefficients (see them in equations (6), (7), and (8)). In some cases, the modified technological coefficients may become zero or even negative. In these cases, the ratios will not be calculated. (Dividing by zero is not possible, and if the technological coefficient is negative, the corresponding resource will not limit the introduction of the product into production. By introducing such a product into the production plan, resource will not be depleted further, but rather an increase in the available quantity of resource will occur.) The following ratios are acquired

for \( x_2 : \frac{600}{4} = 1600 \),

for \( s_1 : \frac{600}{7} = \frac{800}{7} \approx 114.3 \),

for \( s_3 : \frac{60}{7} = 40 \).

The production of product \( P_1 \) is the most limited by the machines’ capacity \( M \). Therefore, the vector corresponding to variable \( s_3 \) is leaving the basis, while the vector corresponding to variable \( x_1 \) is entering the basis. **How can the quantity of manufactured product \( P_1 \) be determined?** Since (8) is the limiting constraint, it can be written in an equivalent form

\[ \frac{3}{2} x_1 = 60 + \frac{1}{3} s_2 - s_3, \]
\[ x_1 = 40 + \frac{1}{3} s_2 - \frac{2}{3} s_3. \tag{10} \]
How are the expressions for determining the remaining basic variables $x_2$ and $s_1$ modified? The found expression (10) of basic variable $x_1$ allows to determine, using (6) and (7), the expressions of the other basic variables

$$x_2 = 400 - \frac{1}{4}(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) - \frac{1}{4}s_2,$$

$$x_2 = 390 - \frac{1}{3}s_2 + \frac{1}{6}s_3,$$

$$s_1 = 600 - \frac{21}{4}(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) + \frac{3}{4}s_2,$$

$$s_1 = 390 - s_2 + \frac{7}{2}s_3.$$

What is the next feasible solution to the solved problem? Which variables are equal to zero? If the non-basic variables are equal to zero again ($s_2 = 0, s_3 = 0$, that means resource $S_2$ and machines’ hours $M$ are fully depleted), the new values for the basic variables are obtained. The new feasible solution is $x_1 = 40, x_2 = 390, s_1 = 390$.

What is the modified profit of the firm? How is the value of the objective function changed? The value of the modified objective function is determined, using (9) and (10), by the expression

$$z = 1600 + 2(40 + \frac{1}{3}s_2 - \frac{2}{3}s_3) - s_2,$$

$$z = 1600 - \frac{1}{3}s_2 - \frac{4}{3}s_3. \quad (11)$$

When $s_2 = 0, s_3 = 0$, then the modified firm’s profit will be 1680€.

Is the acquired solution optimal? Can another solution for which the value of the objective function is higher be found? Let’s analyze the modified objective function (11). The modified coefficients in the objective function are negative or zero, so introducing vectors corresponding to variables $s_2$ and $s_3$ into the basis would decrease the profit (for one unit of resource $S_2$, the loss would be 1/3€, and for one unit of machines’ hours $M$, the loss would be 4/3€). Therefore, the determined solution $x_1 = 40, x_2 = 390, s_1 = 390, s_2 = 0, s_3 = 0$ is optimal. This implies the production plan for the firm with the highest profit. The firm will produce 40 pieces of product $P_1$ and 390 pieces of product $P_2$. Resource $S_2$ and the processing time on machines’ M will be fully utilized. Resource $S_1$ will remain unutilized with a remaining inventory of 390 units.

How can the optimal solution be graphically interpreted? A new displacement by DC-edge is made, up of C-vertex (Figure 5). At this point, the process ends. Vertex C is the optimal solution to the problem.

Using the simplex method [13], the transformed tableau has the form of Table 4. Modified technological coefficients correspond to coefficients in the expressions of variables $x_1, x_2, s_1$, and the objective function $z$.

<table>
<thead>
<tr>
<th>Base</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$s_1$</th>
<th>$s_2$</th>
<th>$s_3$</th>
<th>$z$</th>
<th>$b_i$</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>1</td>
<td>-7</td>
<td>0</td>
<td>390</td>
</tr>
<tr>
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<td>0</td>
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<td>$\frac{1}{6}$</td>
<td>0</td>
<td>390</td>
</tr>
<tr>
<td>$x_1$</td>
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<td>0</td>
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<td>$\frac{2}{3}$</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>$z$</td>
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<td>0</td>
<td>0</td>
<td>$\frac{1}{3}$</td>
<td>$\frac{4}{3}$</td>
<td>1</td>
<td>1680</td>
</tr>
</tbody>
</table>

3 Conclusions

Logistics is the process of planning, organizing, and managing the movement of goods and raw materials in the supply chain. Currently, as new technologies change what logistics work entails, it is more important than ever to help students develop their critical skill set. The combination of critical-thinking skills and experience aids in a logistics professional’s ability to anticipate and visualize processes from start to finish to optimise supply chain settings. It is challenging to find professionals who understand data and its role in logistics planning. Data is the key to making the right decisions, so the ability to analyze data and processes is the basis of education. This means solid knowledge of mathematics is very important. An essential part of good logistics flow is team management. Organizational skills are the requirements of a logistics manager. Teamwork is a vital component of any supply chain management system, as each role in these processes complements one another. Developing interpersonal skills such as patience, empathy, and active listening can help communicate ideas more effectively.

In the context of the rapid advancement of information technology, the educational process faces new and
challenging tasks. Current university students are living under the pressure of an enormous amount of information being pushed onto them in varying quality. The easier accessibility of information conflicts with students' ability to select relevant sources and content based on critical thinking. Therefore, it is essential for students not to be only passive recipients of predetermined algorithmic procedures but to be active in the learning process. It is as well equally important to be able to analyze causal relationships and think about the sequence of steps while solving the problems. An active approach helps them also learn how to communicate properly, recognize errors in their opinions, argue and defend their solutions correctly.

The article aims to highlight the possibilities of a constructivist approach in teaching linear programming problems in the field of operational research and logistics in the context of university education. This approach provides a suitable environment for the development of students' critical thinking. Within solving the optimization problem two mathematical methods were connected and the algorithm was analyzed in detail step by step. The integration of multiple approaches helps students to see the problem in context and teaches them different ways how to analyze the problems and find solutions. This allows them to develop unconventional methods and approaches to problem-solving. Students acquire solution frameworks that they can subsequently apply to solve other problems. Understanding and identifying strengths and weaknesses in the used methods enables students to use the methods correctly and choose them effectively for solving problems.

The young generation will soon face the challenge of not succumbing to artificial intelligence and maintaining information technology at a level that serves humanity. Therefore, seeking new educational approaches that help strengthen students’ skills of critical thinking is a very important necessity.

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