The Role of Thinking and Practical Operations in Overcoming Psychological Difficulties in Solving Physics Problems

Kulush Kenzhegaliyev[1*]
Shaharzat Kuttykozhaeva[2]
Saule Damekova[3]
Mariyam Abisheva[4]
Yelnur Zhumazhanov[5]

[1] Candidate of Pedagogical Sciences, Professor of the Department of Pedagogy, Psychology and Social Work, Sh. Ualikhanov Kokshetau State University, Kokshetau, Kazakhstan. E-mail: kulushk@mail.ru.
[2] Doctor of Physical and Mathematical Sciences, Professor of the Department of Physics and Mathematics, Sh. Ualikhanov Kokshetau State University, Kokshetau, Kazakhstan. E-mail: shaharzat@mail.ru..
[3] Candidate of Pedagogical Sciences, Head of the Department of Physics and Mathematics, Sh. Ualikhanov Kokshetau State University, Kokshetau, Kazakhstan. E-mail: damekova_s@mail.ru.
[4] PhD Student of the Department of Physics and ICT, Sh. Ualikhanov Kokshetau State University, Kokshetau, Kazakhstan. E-mail: mariam_ab@mail.ru.
[5] PhD Student of the Department of Physics and ICT, Sh. Ualikhanov Kokshetau State University, Kokshetau, Kazakhstan. E-mail: elnur3093@gmail.com.

ABSTRACT: This article discusses the mechanism of the psychological difficulties of students in solving problems in physics. This phenomenon is peculiar to students` state when solving problems in other subjects of natural sciences. New concepts of “mental operations”, “practical operations” as a psychological tool of the cognitive process are introduced. A specific technique is given for compiling the “Matrix of mental and practical operations” to overcome psychological difficulties in solving problems in physics.

Keywords: psychological difficulty, problem-solving, mental operations, practical operations, psychological tools, cognitive process.

INTRODUCTION

Research Problem

When teaching physics in high school, problem-solvingplays an essential role in the formation of solid knowledge and skills. As practice shows, students in most cases face difficulties solving problems (Azevich & Alekseeva, 2019).Many teachers do not go into the reasons/details of the process of difficulty in solving problems in physics and mathematics (Kenzhegaliev, 2015). Some researchers of this process note that the reason for the difficulty in its psychological nature and call it Kovalev's“psychological difficulties”.

We attempted to investigate the psychic nature of the process of students' difficulty at the level of mental and practical operations. “The Activity Theory” by A. Leontiev (1971) and “The Doctrine of Higher Mental Functions” by L. Vygotsky (1960) have been chosen as the methodological basis of the study. The process of solving problems is a process of thinking.According to L. Vygotsky (1960), problem-solving is a kind of culture of thinking.The main “psychological tool” of knowledge according to Vygotsky is the sign (word), in our case, all physical concepts, symbols, formulas, connections of physical processes considered in tasks.Based on such thinking, the student's consciousness is built. Problem-solving in physics, according to the figurative representation of Marx, is a specific form of communication with the world. The condition of the task is external nature, as a special tool of knowledge, it is directed to the inner world of the student and transforms him (Rubinstein, 1959). Problem-solving provides new mentalcontent, following the conditions of the problem. Problem-solving gives a qualitatively new content to thinking: the laws of cultural development of consciousness come into effect. Memory and thinkingare the leading functions of school students (Yakovlev & Yakovleva, 2015; Pevtsova, 2020; Kondubaeva et al, 2018; Parvizian, et al, 2015; Kanashiro, et al, 2018).

Operations and thinking in categories of basic physical concepts are described as the main psychological tools for solving problems in "The Activity Theory" by A. Leontiev (1971). He claims that «operation is what the action is performed with». Operations, according to our research, are divided into mental and practical which does not contradict the theory of interiorization of L. Vygotsky (1960).When solving problems, a student should be aware of the learning material at the level of mental operations, which is the main "psychological tool". Then the student performs mental tasks and can translate into external actions in the form of speech or recording.

The problem-solving process is a thought process, the material of this process is the basic physical concepts in the form of elements - mental images of physical concepts, data in the form of symbols, signs, and formulas. The problem-solving process is a mental process. The system of mental signs, symbols, formulas, laws, rules interconnected logically for the functioning of their mental and practical operations is a vital part of this process. These operations are directed first to the inner and then outer area of action. L. Vygotsky (1960) defined these as "internal internalisation" and "external internalisation". According to our research, psychological difficulties are caused by the following teaching mistakes:

1. Methodically incorrect formation of basic physical phenomena and concepts, the complete absence of demonstration experiments.
2. The lack of teaching hours for problem-solving skills development.
3. The lack of psychological training of subject teachers in the psychology of education which has its laws and methods.
4. Psychic causes.

"The Activity Theory" by A. Leontiev (1971) and "The Doctrine of Higher Mental Functions" by L. Vygotsky (1960) have been chosen as the methodological basis of the study. The example of solving the problem in "Molecular Physics"is presented below. It shows the methodology for compiling the matrix of mental and practical operations.

Table 1. The matrix of mental and practical operations

Content	№	Mental operations "knowledge"	№	Practical operations "skill"
Problem (Rymkevich, 1988). During the combustion of natural gas with a volume of 1 $м^3$, under normal conditions,energy of 36 MJ is released.How much energy is released when burning gas with a volume of 10 $м^3$, which is suppressed by110 kPa at a temperature of7 ^0C? СИ $V_1 = 1м^3$ $W_1 = 36$ MJ $36 \cdot 10^6 J$ $V_2 = 10м^3$ $P_2 = 110кPa$ $110 \cdot 10^3 Pa$ $P_1 = 10^5 Pa$ $t_2 = 7^0C$ T_2 -280K Q_2 -? Solution: 1. The calorific value of gas is: $Q = \lambda \cdot m$ 2. Knowledge and ability to find the mass of gas in the form of the desired value: m $=\frac{P}{R}\frac{V}{T}\mu$ It can be seen from the problem that the more gas is burned, the more energy is released $\frac{W_2}{W_1} = \frac{P_2}{T_2}\frac{P_2}{P_1}\frac{T_1}{V_1} \Rightarrow$ $W_2 = \frac{P_2}{T_2}\frac{V_2}{P_1}\frac{T_1}{V_1} \cdot W_1$ $W_2 = \frac{1{,}1 \cdot 10^5 Pa \cdot 10м^3 \cdot 273K}{280K \cdot 10^5 Pa \cdot 1м^3} \cdot 36 \cdot 10^6 =$ $=390 \cdot 10^6 J$=390 MJ Answer: 390 MJ.	1	Symbol of volume and unit of measure	1	Symbol record
	2	Knowledge of theenergy symbol	2	The ability to record the energy symbol
	3	Knowledge ofthe pressure symbol	3	The ability to record the pressure symbol
	4	Knowledge of the scales oftemperature measurement ^0C, K.	4	The ability to convert ^0C to K and vice versa
	5	Knowledge of finding the sought energy	5	The ability to record the sought energy
	6	Knowledge of theenergy unit of measure	6	The ability to record
	7	Knowledge of the gas pressure unit of measure	7	Unit conversion
	8	Knowledge of the gas temperature unit of measure	8	Temperature conversion
	9	λ- Knowledge of the specific calorific value	9	The ability to record
	10	Knowledge of the calorific value of gas formula	10	Formula record
	11	Knowledge of the Mendeleev-Clapeyron equation	11	The ability to extract mass from the Mendeleev-Clapeyron equation
	12	Knowledge of direct proportionality from mathematics	12	$\frac{x_1}{x_2} = \frac{y_1}{y_2}$ - theability to record proportions
	13	Knowledge of the record ofa problem- solving in the form of a proportion	13	The ability to derive the desired value from the formula
	14	Knowledge of solving and transforming tasks	14	Calculation

It can be seen from the conditions, if a student does not have the necessary knowledge and skills at the level of mental and practical operations, then psychological difficulties or psychological barriers to solving problems will arise. All students encounter these difficulties to a different extent. Our study shows that 80% of the respondents faced them. In our example, to solve the problem, it is necessary to know 14 mental operations based on knowledge of theoretical material and 14 practical operations at the level of abilities. If a student performs these 28 mental operations, the task will be solved, the number of operations in different tasks is similar to each other, but the number can vary depending on the degree of the taskdifficulty.

We offer a psychological approach based on the example of solving problems in physics. Subject teachers should be prepared and take into account the psychological characteristics of the subject content. Physics teachers do not have enough hours to develop practical skills and problem-solving skills. A famous scientist-methodologist, professor Usova notes that teachers are in a hurry to keep up with the program, therefore, not enough time is devoted to solving problems in physics and the operational aspect of solving problems is not formed. The operational method of solving problems in physics is a mental state of a student when knowledge and skills are included at the level of mental operations and then go to the level of practical actions. This is the only way to overcome the "psychological difficulty" of students in solving problems.The conducted pedagogical experiment confirms our assumptions that the difficulties of the tasks are not in the content of the tasks, but failure to perform mental operations based on the theory following the proposed problem. The experiment was conducted in Grade 10. Our assumption was tested in accordance with the Student Criterion (Rymkevich, 1988).

Table2. The comparison of skills to solve problems using an operational matrix technique

№	Focus group(x_i)	Experimental group(y_{ii})	$d = y_i - x_i$	$d_i - M_d$	$(d_i - M_d)^2$
1	100	115	15	10	*100*
2	102	102	*0*	-5	*25*
3	105	114	*9*	*4*	*16*
4	120	122	*2*	*-3*	*9*
5	110	119	*9*	*4*	*16*
6	106	116	*10*	*5*	*25*
7	109	100	*-9*	*-4*	*16*
8	115	121	*6*	*1*	*1*
9	115	118	*3*	*-2*	*4*
10	114	124	*10*	*5*	*25*
11	111	119	*8*	*3*	*9*
12	125	121	*-4*	*1*	*1*
13	110	119	*9*	*4*	*16*
14	115	118	*3*	*-2*	*4*
15	100	115	*5*	*0*	*0*
16	100	114	*14*	*9*	*81*
17	102	105	*3*	*-2*	*4*
18	103	106	*3*	*-2*	*4*
19	114	120	*6*	*1*	*1*

20	112	120	*8*	*3*	*9*
21	108	118	*10*	*5*	*25*
22	107	110	*3*	*-2*	*4*
23	105	112	*5*	*0*	*0*
24	110	112	*2*	*3*	*9*
25	112	120	*8*	*3*	*9*
26	111	115	*4*	*-1*	*1*
27	124	109	*-15*	*-20*	*400*
			$\sum d_i=127$		$\sum=815$

$M_d = \frac{\sum d_i}{n} = \frac{127}{27} = 4.7 \approx 5$ - arithmetic mean

$\sigma_d = \sqrt{\frac{815}{26}} = 5.6.$ – standard error (deviation)

$T_{empir} = \frac{5\sqrt{26}}{5,6} = 4,5$ - empirical value of the criterion

For the respondents with a sample of $df=27$ with a probability error of $p \leq 0,05$ of the corresponding accuracy of 0,95 the critical value of the Student criterion in the table is $T_{crit}=2,052$. Comparing, we have: $T_{empir}>T_{crit}$ which means our assumption is confirmed. At the same time, descriptive statistics was conducted. The statistics values were calculated using the Windows Excel program, which was reflected in Table 3(Stevens, 1960)

Table3. Descriptive Study Statistics

№	Name of descriptive statistics	x_i	y_i
1	Arithmetic mean: $M_d = \frac{1}{n}\sum x_i$	5	17
2	Standard error (deviation) $\mu = \frac{\sqrt{\sigma^2}}{\sqrt{n}} = \sigma^1/\sqrt{n}$	1.07	1.4
3	Median	110	87
4	Mode	110	87
5	Standard deviation	5,2	7,1
6	Dispersion	30,1	52,6
7	Excess	0,17	0,13
8	Asymmetry	3,65	1,65
9	Interval (Span)	25	35
10	Minimum	100	65
11	Maximum	125	100
12	Total		
13	Sample size	27	27

CONCLUSION

1. Physics teachers explain the difficulties of students in solving problems in physics not from the point of view of the psychological theory of activity. Attention is not

paid to the mental state of students in solving physics problems at the level of mental operations (Leontiev, 1971).

2. In solving problems in physics, teachers donot use the knowledge of the higher mental functions of the brain (Vygotsky, 1960).

3. Teachers do not pay attention to the work of internal and external internalization of mental and practical activity, they must work synchronously.

4. There is a reasonable suggestion to train physicists and mathematicians on the principle of "two in one", both a psychologist and mathematician.

Teaching and problem solving should be carried out at the level of mental regulation of mental operations through the formed psychological tools: concepts, formulas, physical, mathematical laws, etc.

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