MODALITIES TO OPTIMIZE THE ENGINEERING EDUCATION THROUGH PROBLEM-BASED TEACHING AND LEARNING

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Major requirement:
Learning must change the behaviour.

Abstract *¾ The method of problem-based teaching and learning is a didactical method with a pronounced heuristic, formative and participative character, what makes it suitably to face the actual challenge in engineering education. Nevertheless, the traditional barriers by the application of this method have to be broken. In order to optimize the engineering education through problem-based teaching and learning and looking forward, the paper offers some useful answers to some important questions, which have been elaborating as working models/support for both the teachers and learners, with an emphasis on the assessment process. The most of these answers have been synthesizing in the paper in the form of tables, graphics and schemes, which allow an easy overview upon the questions put in discussion. The content of the paper represents also a broadly evaluation of a new way to a better application of a traditional didactical method and a dissemination of good practice.*

Index Terms ¾ Braking traditional barriers, Engineering education, Good practice, Problem-based teaching and learning,

INTRODUCTION

Assessment of student learning is now more important than ever, due to the actual tendency of globalization and the increase of the complexity of the scientific and technical problems. In these conditions, a multi-disciplinary approach of engineering education and a problem-based teaching and learning in this field, oriented towards creativity, become necessary.

Due to the pronounced dynamism of the modern didactic, the teaching/learning methods are permanently reconsidering, enriching and particularizing. Thus, it is difficult to find a unique classification of the teaching/learning methods. Resorting nevertheless to a certain classification, it can be emphasized the fact that ***the method of problem-based teaching and learning belongs to the category of the formative and participative didactical methods***. This classification is basing on the following two ***criteria:***

- ***The nature of the operational educational objectives,*** which are achieving through the didactical method applied. Analyzed accordingly to this criterion, the method of problem-based teaching and learning, facilitates in a great measure the attainment of the ***"formative" objectives,*** which concern both the formation of the competences/skills and the development of the cognitive processes of the future specialists. Through the application of the method of problem-based teaching and learning, the educational process gets a preponderantly formative character.
- ***The level of participation*** of the student at the instructive-educative actions, i.e. the measure the student is participating direct, conscious and active, with .personal effort, to its own formation.

Therefore, the problem-based teaching and learning enjoys a special reputation in the contemporary didactical methodology. The aim of the paper is to offer a contribution to a more efficient application of the method of problem-based teaching and learning in the field of engineering education.

PROBLEM-BASED TEACHING/LEARNING - A DIDACTICAL METHOD PLENTY PRAISED. GENERAL CHARACTERIZATION

The method of problem-based teaching/learning has two important attributes: formative and participative. These are decisiveness for a modern engineering education. Alongside of other didactical methods, the problem-based teaching/learning belongs to the category of the heuristic methods, applied in education in order to release the independent activity, the personal thinking and intellectual effort of those who are learning. The priority is not only to improve and enrich the amount of knowledge (the situation "to know"), but to develop and perfect the activity towards knowing (the situation "to elaborate and discover the way towards verity", the solution of the problem), to develop the intellectual capacities and functions of the student (inventiveness, creativity). The accent is put on the stimulation of the older knowledge - with the aim to promote other new knowledge - and on the awareness of the student upon his own activity, which determinates a more intensive participation of the student towards his own development.

Even the simple fact that the student has to face a problem and is trying to solve it independently constitutes for him a beginning to a new knowledge and to an

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intellectual growth. There was already recognized that not the accumulation of information assures by its own the development of the students thinking, as chiefly the act to operate with the logical functions of the intellect in order to discover and acquire knowledge.

With this finality, the process of teaching and learning is performing through setting up and solving problems with special characteristics, different from those used within the traditional education and within the method of exercise-based teaching/learning.

ATTENTION! A problem-based teaching/learning should not be confound with the solving of stereotype problems, with a given algorithm (formula, law etc.). The problems which are solving as application, on a method known by the students, are not proper to be included into problem-based teaching/learning.

Within the frame of a problem-based teaching/learning there are ***two fundamental concepts:*** the **"PROBLEM"** and the **"DOUBTFUL-SITUATION".**

The PROBLEM is a cognitive difficulty (gr. "pro-ballein" = what is thrown in face as obstacle), a requirement in face of which the register of answers of the subject is insufficient and inadequate. The solving idea is always to find the unknown element; in fact the problem is a structure with insufficient dates. In order to find the solution of the problem, besides supplementary information, usually is also necessary to reorganize (restructure) those existing and, sometimes, to reconsider them.

On the psychological level, the appearance of a problem implicates a cognitive and emotional-affective conflict in the consciousness of who is trying to solve it, due to the difference between what is known and what must be found. The situation of the conflict between the necessity to solve a problem (to find the answer to a question) and the unsatisfactory character of the knowledge and the working techniques possessed by the student in the respectively moment is generating a psychological tension which is releasing the curiosity of the student, is arousing its interest and determines the student himself to seek for the solutions and for the ways to get them. Thus, in proper pedagogical conditions, can be attained a real learning through discovery, with a large manifestation of the students creativity, inventiveness and capacity to solve personal, on an original way, diverse problems.

The DOUBTFUL-SITUATION is defined as a task with a newness character, which is denying, totally or partially, the previous knowledge and convictions of the student and which, like the problem, is generating a state of psychological tension, leading to the elaboration of a new solution, with new cognitive elements. So every doubtful-situation presumes a contradiction between the earlier (older), incomplete, un-reorganized information and the solution. Every contradiction which is overturning a conviction is in accordance whit the aim of problem-based teaching/learning.

The disclosed contradiction is creating a cognitive unbalance, attended by a certain bewilderment, astonishment, uneasiness and uncertainty, which is releasing an action to re-establish the balance, the concordance between the knowledge level of the student and the scientific level concerning the problem studied. In essence, basing on old dates, there is to compose and re-compose cognitive systems and structures with new functionalities, inclusively through a completion with new information.

The method of problem-based teaching/learning is applicable independently of the nature of the discipline (theme) and the organizational frame in which it is applying, evidently in a different applying mode, in accordance with the educational-instructional objectives and teaching/learning conditions. But, like any method, the method of problem-based teaching/learning has certain limits, imposed by both the content of the activities and the didactical conditions in which it is applying. Consequently, the method of problem-based teaching/learning cannot be considered as a universal method capable to replace the other didactical methods, beside which it is applying. However, due to its efficiency, the method of problem-based teaching/learning deserves priority in any cases the didactical conditions allow so.

CREATING THE PROBLEM-FRAMES – A MATTER OF OPTIMIZATION

The problems and the doubtful-situations can practical be created in many sorts. Interesting for any teacher, who is wishing to perfect himself in the application of the method of problem-based teaching/learning, are the answers at the following ***five questions:***

1) How can be distinguished the properly problems for problem-based teaching/learning from the improperly one?
2) Which are the best modalities to create problem-frames for the students, in both of the categories of problem-based teaching/learning activities: with "problems" and with "doubtful-situations"?
3) When have to be used "problems" and when "doubtful-situations" in didactical activities with the students?
4) Which are the role and status of the professor and the students in a process of problem-based teaching/learning?
5) Which are the best possibilities to structure the processuality of problem-based teaching/learning?

All these questions are plenty justified. Some answers to the first three questions could be found out of the tables 1, 2 and 3.

A ***chain-problem-based teaching/learning*** is not easy. It requires from the teachers a solid psycho-pedagogical preparation, completed by a certain didactical-methodological experience (s. figure 1).

TABLE I

THE CHARACTERIZATION OF THE PROBLEMS HAVING IN VIEW THE POSSIBILITY TO USE THEM IN PROBLEM-BASED DIDACTICAL ACTIVITIES

PROPERLY problems	**IMPROPERLY problems**
The unbeknown is containing in the data of the problem only implicit, i.e. in a hide, discrete form, which must be deciphered.	The unbeknown is containing in the data of the problem in an explicit mod, permitting so a rigorous determination
The solving way (the algorithm) is NOT known before by the student (the problem has not a stereotypical character).	The solving way (the algorithm) is known before by the student (the problem has a stereotypical character).
Constitute a real theoretical or practical difficulty for the student. The resolving is possible only through personal efforts, seeking and contributions.	Do not constitute a real difficulty for the student (the problem is artificially, a pseudo-problem). The resolving is possible without personal efforts, seeking and contributions.
They are able to contribute to the creation of an intellectual seething atmosphere during the activity.	Do not generate any cognitive conflicts and neither a state of psychological tensions at the students.
Are formulated in such a manner that the students can easily discern and understand the problem and concentrate their attention upon its resolution.	Are formulated confused or in such a manner that it is difficult for the students to understand the essence of the problem.
The data of the problem are assuring the motivation (the wish for a solution and the acceptance of the personal effort required in this purpose) and are releasing one or more hypotheses for the solution of the problem.	Do not contribute to the creation of the motivation.
Through the resolution, the student is getting new knowledge and is developing its intellectual capacity.	Through a repetitive application there is creating at the students only automatisms.

An acceptable answer concerning the third question could be: the problems are indicated when the students are meeting the respectively problem at the first time and so they have not yet any formed convictions, while the doubtful-situations are indicated in those cases in which the students have already certain formed convections (erroneous or unsatisfactory) about the respectively problem.

TABLE 2

MODALITIES TO CREATE A PROBLEM-BASED DIDACTICAL FRAME THROUGH "PROBLEMS"

The type of the problems	**Requirements concerning the personal effort of the student**	**Examples of guidance**
1. Questions (problems) solved through a creative processing of prior knowledge and through the selection, from this system of knowledge, of those needed for the concrete solving of the task.	• To reorganize the prior assimilated knowledge. • To establish correlations and analogies. • To realize deductions. • To argue principles. • To establish the significance of a fact. • To compare the studied objects and phenomena. • To classify these on certain principles, criteria etc.	➢ The deduction of the causes of a phenomenon, beginning from the facts known by the student or offered by the professor. ➢ The deduction of the effects of a phenomenon or process etc.
2. Questions (problems) solved on more ways. For example in activities in laboratories, workrooms, projection, research, development etc.	• To mobilize the cognitive resources. • To think creative. • To think logically. • To imagine. • To investigate. • To observe. • To associate. • To select. • To decide. • To verify (inclusively experimental).	➢ The realization of installations, machines, apparatus, communicating to the students only the functionally qualities of the product of the activity. ➢ The finding of solutions for the discovery and repair of the defects of apparatus, machines, installations etc.
3. Questions (problems) solved through the application, in new theoretical and practical conditions, of the prior knowledge.	• To establish new relations between objects and phenomena, or between the parts of a system. • To study processes in statically schemes (systems) etc.	➢ The determination of the behaviour of a technical system in new, not studied yet, basing on the knowledge concerning other working conditions studied earlier. ➢ The demonstration of the equations, in new working conditions, of a given system, starting from a known general scheme etc.

TABLE 3

MODALITIES TO CREATE A PROBLEM-BASED DIDACTICAL FRAME THROUGH "DOUBTFUL SITUATIONS"

Crt. nr.	The type of the doubtful situation		
	The variant of the contradiction/conflict/incongruity/disagreement		**A.** The question (addressed by the professor)
	The previous knowledge. (The old experience) **?**	**?** The professor's affirmation (The new experience)	**B.** The requirements of personal effort of the student **C.** The result
1.	The disclosure of the contradiction between the previous experience of the student (knowledge, capacities, skills etc.) and the scientific explanation of the studied facts and phenomena.		
1.1.	Wrong empirical knowledge of the students.	The scientific reality, which must be explained and conceived.	**A.** How to explain? Why? **B.** Comparison. Correlation. Logical thinking. Analyze/Deduction. Synthesize/Induction. Argumentation. Generalization. Verification. Conclusion. Reconsideration/Reorganization/Reconstruction of knowledge etc. (dependent on the case). **C.** A more correct and complete understanding of the scientific reality and the integration of this into the system of knowledge of the student. The enhancement of the intellectual capacity of the student.

TABLE 3. (Continuation)

<table>
<tr><td rowspan="3">Crt. nr.</td><td colspan="3">The type of the doubtful situation</td></tr>
<tr><td colspan="2">The variant of the contradiction/conflict/incongruity/disagreement</td><td>A. The question (addressed by the professor)</td></tr>
<tr><td>The previous knowledge. (The old experience) ?</td><td>? The professor's affirmation (The new experience)</td><td>B. The requirements of personal effort of the student
C. The result</td></tr>
<tr><td>1.1.</td><td><u>Exemplification</u>:
The weight is an intrinsic property of the bodies.</td><td>The weight is not an intrinsic property of the bodies.</td><td>A. How do you explain the different behaviour of the bodies in the gravitational field and outside of this?
B. The scientific explanation of the concept of weight.
C. The understanding that the weight is a result of the interaction of the bodies.</td></tr>
<tr><td></td><td colspan="3"><u>Observation</u>: · This type of doubtful situations is referring first to those concepts/notions met first time by the students.
· The difficulty and the complexity of this type of doubtful situations are increasing stepwise at the same time with the consolidation of the scientific truth in the mind of the students.</td></tr>
<tr><td>1.2.</td><td>Already accumulated knowledge (previously conceived) by the students with respect to the given problem.</td><td>New information (scientific reality), tending to reconsider and to reconstruct the previous experience or to complete it. (Or new scientific reality to discover)</td><td>A. Why? When? Where? How? etc. (for example in phenomenological analyses). What if? (With a projective, anticipative sense).
B & C. Similar to 1.1.</td></tr>
<tr><td></td><td><u>Exemplification</u>:
Every body is in a relative dormancy or in a linear and uniform movement if no forces are acting upon it.</td><td>No body is taken away from the action of other bodies.</td><td>A. If no body can be taken away from the action of other bodies, what means that upon every body are acting forces, than how do you explain the utility of the first law of the dynamics?
B. The scientific explanation of the conditions in which the first law of the dynamics is applying.
C. The correct understanding of the state of equilibrium and linear movement of the bodies.</td></tr>
<tr><td>1.3.</td><td>The knowledge of the students according to the past state of the science and technique. (Anterior information).</td><td>Information regarding to the new discoveries in science and technique, which are negating/refuting the old information.</td><td>A. Why? In what conditions? Which? When? Etc.
B. The overturn/pulling down/reconstruction of the old system of knowledge and the representation and construction of a complete new structure, in accordance with the scientific truth.
C. The amelioration of the system of knowledge of the student, through the elimination of the nonscientific information, the integration of the new scientific truth and the reconstruction of the system of knowledge.</td></tr>
<tr><td>2.</td><td colspan="3">The emission, by the professor, of some different points of view, approaching modes or hypotheses regarding to a problem, the student having to compare them and to verify them, in order to select the best (the more correct, simple, economic, elegant), basing on the anterior knowledge.</td></tr>
<tr><td>2.1.</td><td>Limited anterior knowledge of the student regarding to the given problem. Another anterior knowledge not linked to the given problem.</td><td>More alternatives (points of view, approaching modes, hypotheses etc.), not necessarily all of them with scientific character, regarding to the given problem.</td><td>A. Which? On what a way? In what conditions? On what method? Etc.
B. Critical analysis. Argumentation (for the rejection of those, which are nonscientific). Comparison. Correct selection from more alternatives. Verification (theoretical and/or experimental) concerns the validity of those seeking out the hypotheses (sometimes).
C. S. 1.1. & 1.3.</td></tr>
<tr><td></td><td><u>Exemplification</u> (as guidance):
Methods (algorithms) for solving categories of problems, which differ from the category of the given problem.</td><td>More alternatives (approaching modes, resolving hypotheses), proposed by the professor (students) for the solution of the given problem, not studied yet by the students.</td><td>A. Which is the most suitable resolving hypothesis in the given conditions?
B. S. above (2.1.B).
C. Finding out the correct hypothesis, applicable in the given conditions</td></tr>
<tr><td>3.</td><td colspan="3">The revealment of the different behaviour of the objects and phenomena in different conditions (contexts, situations) and the explanation of this behaviour.</td></tr>
<tr><td>3.1.</td><td>Facts and phenomena that are happening normally (constitute the general rule and represent the "normal").</td><td>Facts and phenomena that appear abnormal or in abnormal conditions.</td><td>A. Like at 1.1.
B. Like at 1.1.
C. Like at 1.1.</td></tr>
<tr><td></td><td><u>Exemplification</u> (See also the example represented through the figure 1): The fuel requirement of the automobiles is increasing with the velocity.</td><td>Increased fuel consumption appears at the automobiles not only at high velocities, but also at slow velocities.</td><td>A. How can you explain this fact?
B. The explanation on a scientific way of the "phenomenon of internal burning".
C. A better and more complete knowing of the processes of internal burning at the thermal motors.</td></tr>
<tr><td>3.2.</td><td>The theoretical way to realize a thing (object, phenomenon, process etc.).</td><td>The practical impossibility to realize this thing (object, phenomenon, process etc.)</td><td>A. Why? What is the cause? How can you explain?
B & C. Idem 1.1. - 1.3.</td></tr>
<tr><td>3.3.</td><td>The manner in which a phenomenon should occur (accordingly to the theory)</td><td>The real manner in which is occurring (practically) this phenomenon.</td><td>A. Why? What is the cause? How can you explain?
B & C. Idem 1.1. - 1.3.</td></tr>
<tr><td>4.</td><td colspan="3">The discovery of the error existing in a logical or mathematical sophism.</td></tr>
<tr><td>4.1.</td><td>A reasoning, relation or scheme, accepted as correct until the respective moment.</td><td>Facts, dates etc. that are refuting the respective reasoning, relation or scheme.</td><td>A. Idem 3.2.
B & C. Idem 1.1. - 1.3.</td></tr>
</table>

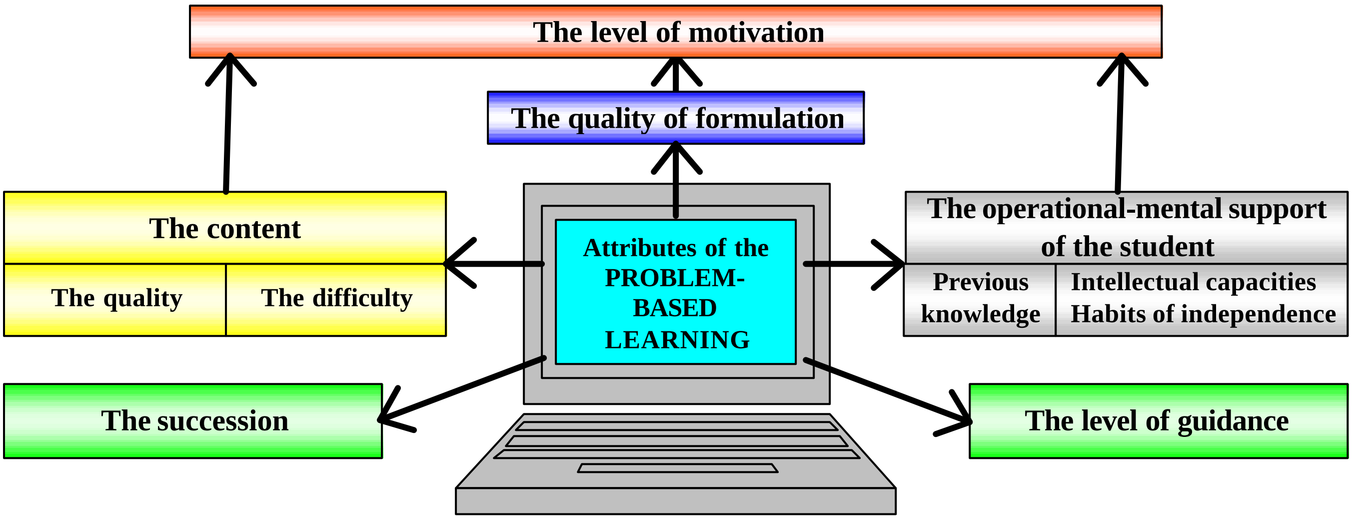

FIGURE. 1
NOTICE TO THE TEACHERS WHO ARE APPLYING THE METHOD OF PROBLEM-BASED LEARNING.

THE STUDENT AND THE TEACHER IN PROBLEM-BASED ACTIVITIES

The fact that the problem-based learning is intensifying the activity of the students, making it more independent and productive-creative and rising it to the first rank (s. figure 2), does not diminish the role of the teacher.

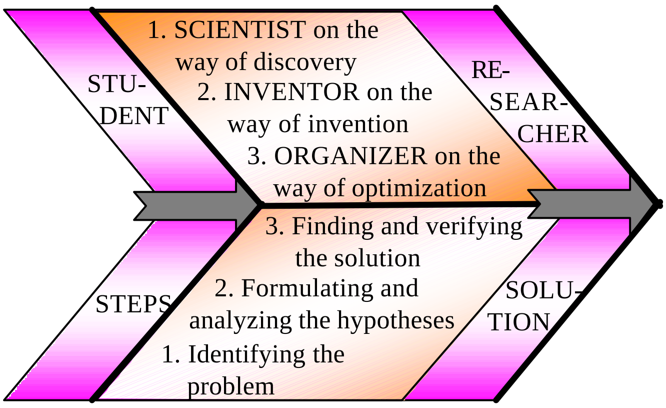

FIGURE. 2
THE THREEFOLD IDENTITY OF THE STUDENT DURING THE PROBLEM-BASED LEARNING.

In such conditions, the teacher becomes an organizer, a coordinator and a guide of the problem-based activity and also a co-author of the solutions given by the students. It means in fact, that the teacher becomes a factor which is assuring the success (s. figure 3).

ATTENTION! The guidance which can be given to the students has a certain limit and to go beyond this limit means sometimes to commit, although with good intentions, a pedagogical mistake (s. also figures 4, 5 and 6).

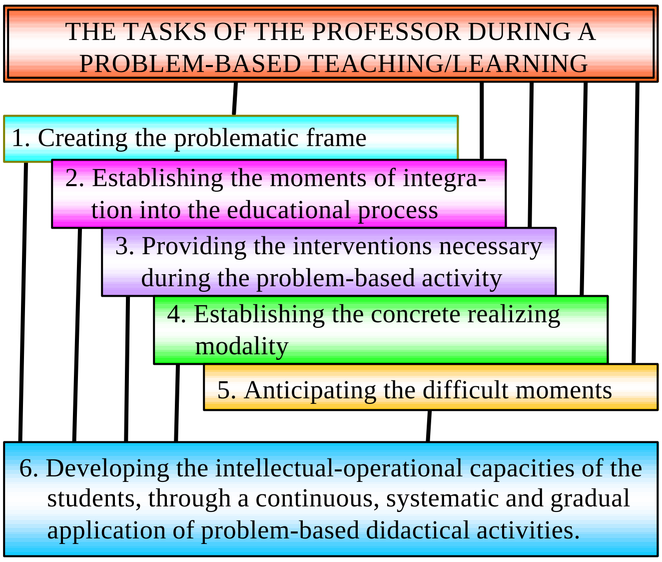

FIGURE. 3
THE TRANSLATION OF THE PROFESSOR'S ROLE IN PROBLEM-BASED DIDACTICAL ACTIVITIES

The help given by the professor may consist in:

- Canalizing the students thinking.
- Supplying methodological information and suggestions, without to go beyond the limits admitted by the pedagogical intention of the method of problem-based teaching/learning.

A POSSIBILITY TO CONCEIVE THE PROBLEM-BASED ACTIVITIES

Relating to the fifth question, the processuality of the problem-based didactical activities could be conceiving also respecting the model shown in figure 6, which contains the main steps recommended to be followed.

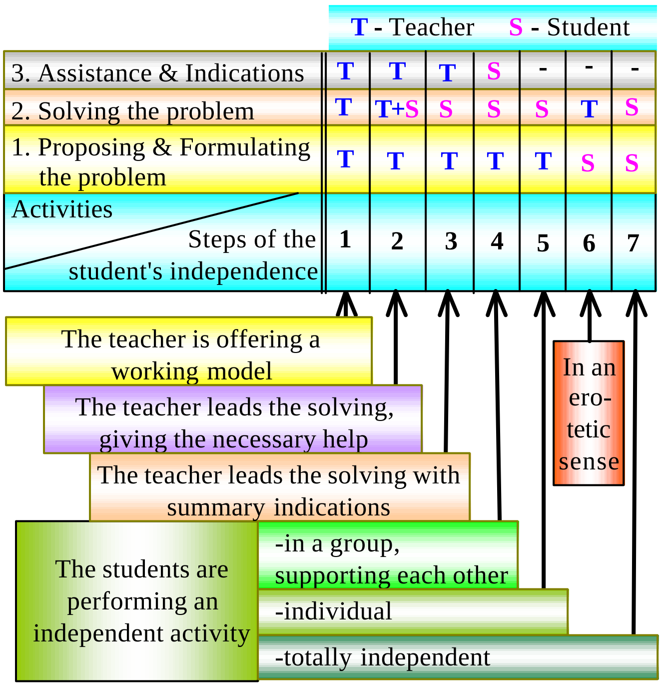

FIGURE. 4
SYSTEMATIC GRADUAL STEPS OF THE STUDENT'S PARTICIPATION AT THE PROBLEM SOLVING.

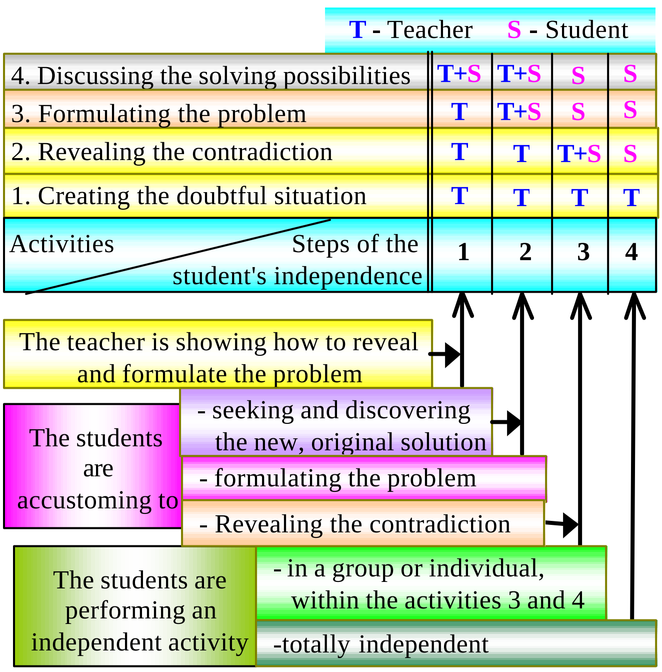

FIGURE. 5
SYSTEMATIC GRADUAL STEPS OF THE STUDENT'S PARTICIPATION AT THE DOUBTFUL-SITUATION SOLVING.

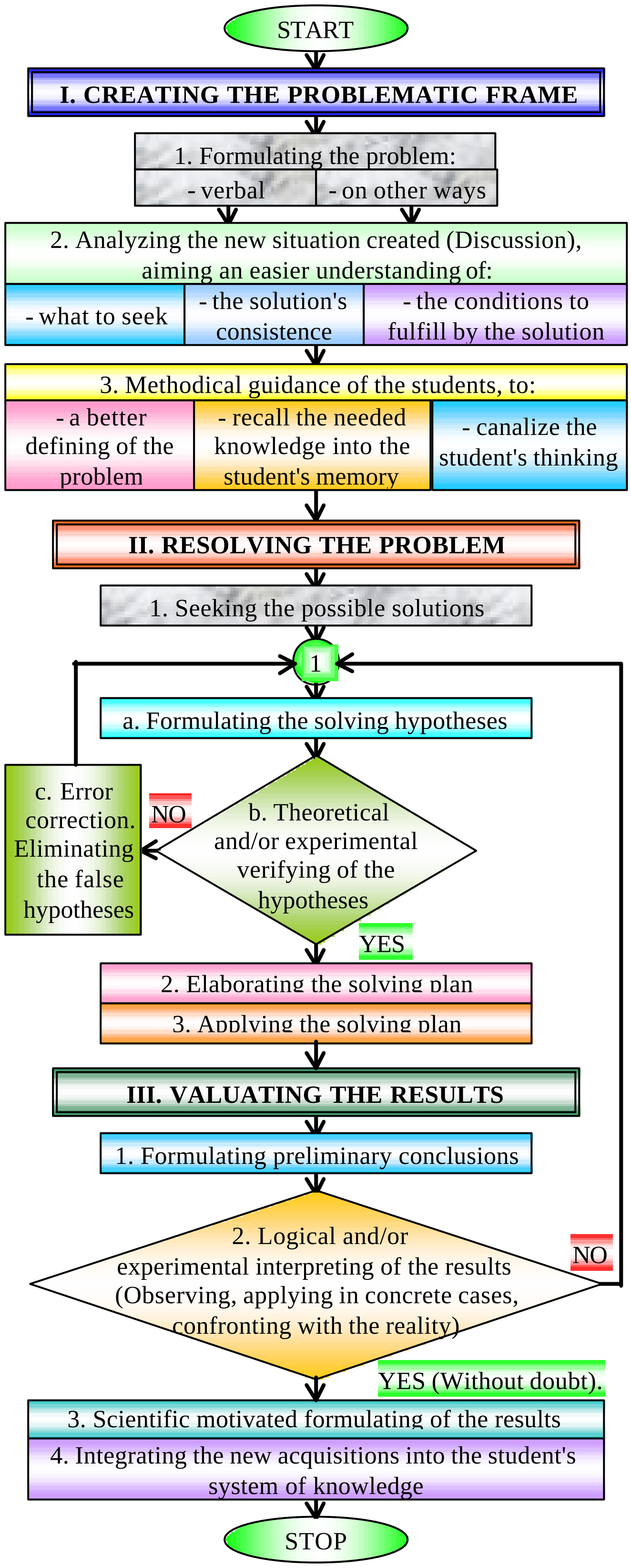

FIGURE 6.
A POSSIBILITY TO CONCEIVE THE PROBLEM-BASED LEARNING.