LOOKING FOR STUDENTS’ PATHS

There are paths neither leading to decisive solutions nor replacing any of students activities. Paths which stimulate to thinking and analysing a problem from the moment it was stated and gently and almost imperceptibly leading the student towards a solution. Leading is not performed by asking obvious questions which already imply answers convenient for the teacher. Instead the student is let to think on his own seeking step after step for a solution. Student has to formulate own hypothesis, look for arguments in its favour or arguments challenging its correctness. He has to test ideas, to err, to overthrow earlier conclusions, to persuade himself. The effort leads to developing new knowledge and gaining new experiences and that all on a very solid basis. Contribution from the teacher is important: he should lead the students in an almost unnoticeable manner, providing encouragement and supporting students own activities. This kind of teacher’s approach builds students self-confidence and encourages to further explorations. Teacher accepts students to share responsibility for the class lesson. At the end questions turn out to be even more significant than solving a specific problem.

Key words: neuroscience, „good question”, education, effective teaching

IDEA

Probably all teachers know how much energy is lost today in Polish schools. How many good ideas remain in the heads and are never verbalized in the class, probably only the students are aware. How much good can be done if one forgets the differences and starts looking for common points, know who try to move forward a step every day.

We are constantly struggling with the quality of knowledge and skill levels of the people whom we are to teach. In principle, this problem in all its brilliance is manifested in the high school and then together with the young man is transferred to the reality of higher education, both the university and the engineering academy or other technical schools. In the upper secondary school walls, the fight for the best possible preparation of the student for both: the matriculation and to study constantly takes place (or at least should take place). This process is not easy. In addition to the obvious factor of individual predispositions for maths, there are many more to be considered. We must take into account the mental, social and increasingly culture aspects. We also need to open up to the neurobiological foundations of learning (Spitzer, 2012). The students are changing, live in other realms, their brains are bombarded with stimuli, neither of which kind nor quantity we have not even dream about a dozen
years ago. This also needs to be taken under consideration. In general, in order to achieve the best possible development of each student, we strive to create a brain-friendly atmosphere (Żylińska, 2013), friendly teaching, friendly work and effort. Willing or not as teachers we play a leading role in this process. To a great extent this atmosphere and the result of students' knowledge will depend on us. Our authenticity, congruence, emotional maturity and empathy are at the heart of student success (Sikorski et al., 2015). It is clear that interpersonal relationships are of great importance in this area (Żylińska, 2013). Probably everyone agrees with the statement that if there is a positive relationship between the teacher and the group he works with, their joint work will be more effective. Good atmosphere based on mutual respect and understanding allows for free exchange of thoughts, views and ideas. It is easier for a student to report his or her approach if he or she feels safe. Being aware that you will not be criticized by the teacher or appear ridiculous in the eyes of other members of the group gives you the power to come up with your idea. It is not, of course, the uncritical reception of any conclusion. It is important for the teacher – acting as an expert – to refer only to substantive issues, apart from any remarks referring to the person. It is important that even wrong methods are analyzed taught by the teacher to show in them some qualities. It is important to use every opportunity to strengthen the sense of student's value and his openness. Especially in view of the fact that we are well aware that there are serious problems with conditional causality in Polish school. In the configuration “stick – carrot” it is the first which dominates. That is bad. Fear is not conducive to creative processes (Spitzer, 2012), nor to learning. And yet it is well known that the best results are achieved in a safe environment where the level of stress is maintained at the right level. New content and skills are best learned when a student feels favor and kindness towards his / her person (Sikorski et al., 2015). Stress also makes the student’s results not really reflecting the actual level of his or her knowledge and skills. We know cases when students in their “safe” conditions manage to solve a task, but during the test they are not able to repeat what they were able to do several hours earlier. It is easy to qualify this student for a defined group. The “label” gained this way very often stays with him/her for many years, effectively preventing her/his development and use of her/his potential. This case is caused by many reasons. It is better to focus on the tools to change it. There are great possibilities in front of the teacher in relation to this issue. At the same time, along with the importance of his role, he must be aware of the responsibility that lies with him. The teacher must know that in the teaching process his or her person is of fundamental importance. It can not be ignored. To make it possible the teacher must meet two basic conditions. First, he must be an expert in his field, in this case in mathematics, so as to be able to open up to discussions with students, to verify the proposed way of reasoning, to find errors, gaps, and failures, and to show strengths of this reasoning. Second: he must be aware of the processes that take place in the brain during the learning process so to use them for more effective teaching, to prepare lessons according to the knowledge of neurodidactics and neuropedagogy.

All of the achievements of above sciences lead to one conclusion. Since the brains of our students process information in a different way comparing to the pupils' brains of pupils over a dozen years ago, we need to take it under consideration while developing our curricula. We're not talking about radical rejection of everything that has been done so far and building everything from scratch. No. It is rather about looking at the facts and applying the corrections required by the present times. We can not persist in believing that since we have worked...
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so for over a dozen years, we should continue to cultivate all the methods we know so far. As we use new technologies in other areas of life, we should open ourselves to changes in the field of education. Nobody sends telegrams today just because it was just done 40 years ago.

Let us see that even small changes can be a foundation for better teaching. Let, according to the knowledge provided by neurosciences, the beginning of each lesson will be its most important and the most attractive part – since this is the moment when student’s brain decides whether the subject is attractive and worthy of interest. Let the content be passed by the feeding method – because the rules discovered by ourselves are left in the brain for longer. The stress level should be controlled – because both too big and too small will work unfavorably.

The teacher should be properly educated, both in his/her subject matter and in the field of rules governing the teaching in the brain – since it is a teacher who is the most significant link of the lesson. In the class, let us have the atmosphere of partnership of the goal pursuit, mutual respect, acceptance and understanding – because the brain is a “social organ” and works better under such conditions (Sikorski et al., 2015).

We need to look for such scenarios that will allow the teacher to meet above demands. In addition it has to include satisfaction to all the conditions and constraints of the formula of school lessons. Once again the role and responsibility of the teacher has to be emphasised. Solid preparation of the teacher is the starting point for further development of this theory and work. It is considered both: preparation during the specialist studies and also preparation for each lesson with students which is the teacher’s obligation.

The temptation to reach for ready solutions is very strong. Conducting lessons in the funnel formula is simply easier, as there are ready-made rules in the market to guide the student from the teacher’s questions to the answer the questioner wants to receive.

It’s also easier because there is no place for surprise, unforeseen developments, action dynamics. Everything happens according to a predetermined course of events. Further questions impose expected answers. If questions are not answered – the teacher give answers himself. The teacher is controlling the lesson indisputably. The pupil’s role is to listen what the teacher is saying and participation in the lesson consists in passive listening and accepting what is being taught. Its activity is limited to the minimum associated with the uncommon response to simple questions posed by the teacher. The monotony and predictability of such activities, as well as the awareness of being just a passive participant are not conducive to development, creativity nor increasing of knowledge. However, there is a path that does not provide ready-made solutions nor performs any operations for the pupil. It allows the teacher to lead student thinking from the problem to its correct solution. But this does not lead through obvious questions suggesting the answers expected by the person asking the questions. This is the essence of the thing that a student looking for himself makes another step towards finding the answer. Unlike obvious, suggestive answers to questions that require only the student’s basic knowledge and awareness of certain patterns, she/he must hypothesize, prove or refute her/his hypothesis, test ideas, be mistaken, withdraw from previous conclusions, convince her/himself – in one word: to work. And it has to be hard work, involving all her/his knowledge and skills. This effort results in building new knowledge and gaining new experiences. The more valuable that he/she has worked it out alone or with discrete assistance of the teacher.

To make this happen, the contribution of the teacher is important. He must prepare a series of questions that will guide students

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in a way that is almost imperceptible to them. To convince them that they are able to discover something by themselves, building their self-confidence and encouraging further efforts. Such questions are called “good”. They make lesson dynamic as there is no single correct answer. A teacher asking a question that can give rise several interpretations agrees that the students will take a great deal of responsibility for the lesson. Any answer may imply further questions, further routes and may cause further problems. Launching this lesson, the teacher must be aware that student reasoning can lead us in different directions. Obviously, the effort that the teacher must take is undisputable. First, he has to prepare the questions. They must stimulate the creativity of the students. They should suggest the direction of thinking, encourage them to ask further questions, raise doubts, break stereotypical thinking, force them to go beyond the known patterns. It requires a lot of experience, great intuition and a lot of teacher work to choose from a huge number of tasks those which contribute with possibility of students’ development. They must be placed in a new situation that requires thinking and revising their current habits. On the other hand, the problem must be reachable by a student. Possibility to solve it in several ways would be a perfect situation. Then, apart from the searching the solution itself, his/her idea and other methods as well as the optimal way of reasoning should be discussed. It is extremely valuable in reference to the development of mathematical skills. Secondly, the teacher may have to react ad hoc to the dynamic situation, eg. respond to questions posed by students. The most challenging is that those unexpected questions may be difficult and go beyond the area of the discussed math problem. It is a challenge for the teacher, but it also a practice.

In addition, such joint work gives you the opportunity to learn the ways of student thinking. Observation of the process of solving tasks and their analysis provides the chance to draw conclusions from their work. What is good, what can be improved, which examples are better affecting pupils’ imagination and how they should be presented to be effective in reaching them. Those effects are not to be achieved while demonstrating the task with its solution when students passively copy the method imposed by us without any impact on its course. Usually, information about their understanding and to what extent they follow this perception comes only while testing them when it is too late for discussion on the problem. Third, one has to agree that in this case the time makes additional cost. Allowing the students to walk freely to the solution will take more time than the presentation of the ready solution on the board. However, the profitable growth of the students is worth this time. Let us not forget that they learn not only to looking for a solution but also to create hypotheses, verbalizing them, proving or refuting them, using the language of mathematics and improve the skills of mathematical discussion.

So it is necessary to look for such tasks. Among the many included in the various publications we should choose those classified as “good questions” allowing us to apply the “tube method”. We can also come up with them ourselves. This is not easy. Firstly because for each of them a framework of questions that are to discretely control student reasoning has to be developed. Obviously we have to be aware that it might surprise us and we need to react ad hoc. In addition, to find out if a problem can be used by us in this context, we must experience it in the class. Propose it to pupils for “processing”. Only then will we see whether our theoretical assumptions may be confirmed in practice. This is why the idea of experiment is appeared..... The result of the experiment should be the development of a method which – implementing the postulates of neurosci-
ences – would allow the teacher to change the teaching of mathematics in his/her classes. Perhaps not in a revolutionary way. Perhaps not in the spirit of changing the whole worldview. Let us hope, however, that it will instill in him an idea of a slightly different teaching. It will make a teacher aware of the facts inducing to a deeper reflection on the methods of his/her work. Every cogitation may contribute with something new, good and valuable in the broad field of the education of a young man.

**RESEARCH**

Discussed experiment is expected to take just over a year. It began in May 2016 as a series of optional meetings for students of two classes of general secondary school. Both groups are made up of second-graders, with extended mathematics curricula. They were selected assuring that the initial conditions in both classes were the same, so as not to distort the later results of the experiment. The main task is to prepare for matriculation exam in mathematics at the expanded level in 2017. One of the groups became an experimental group, where the work is implemented with the “tube method”. The second, control class works with the “funnel method”. The full cycle of preparation is divided into the work phases and the control tests – equally in both groups, conducted at the same time, so as to eliminate the possibility of contact between members of different groups. The obtained results are to be analyzed and subject to statistical analysis. The matriculation exam in May 2017 is the final phase. Detailed statistics analysis of the results of the matriculation exam of students in both groups to help in answering the question if the “tube method” indeed works.

Considering the importance of psychological conditioning in the initial phase of the project, both groups have been examined with the survey to determine – among others – the level of motivation and engagement of the respondents in the preparation for the matriculation exam. In order to monitor this situation, another survey is planned in September. The goal is to make comparison with already received data. Information on the transformation of above mentioned indicators with the approaching the matriculation exam. September is the beginning of the new school year. At the same time it will be the last year at school for respondents. It seems to be interesting what the students think and how they feel at the beginning of the last eight months in front of one of the most important examinations. The questionnaire of the survey was divided into three groups of questions.

The first concerned plans for the future. Students were asked to determine to what extent they have already defined their further development and what the role mathematics will play in it.

It is noticed that students who are following the choice of mathematics as an extended subject associate their future with this field. Most of the respondents declare that they have already predetermined their degree of study and that the results of the matriculation exam in mathematics are taken into account in the recruitment process takes. This provides the basis for believing that the motivation of the students will be based on internal motives. This result will decide on their near future. It will not be a matter of pressure from parents or school, but will come from their inner imperative.

The second group included questions about the approach to the subject. The goal was to diagnose what the students’ attitudes to specific tasks are, how they affect the new, non-obvious problem, how they behave when the solution to the problem requires intensive work and unconventional methods, what are their feelings after solving the problem, or how easily they are to come to give up and resign solving the
Are the studies you are considering related to mathematics (as a goal or as a tool)?

![Graph showing responses to the question about studies related to mathematics]

**Fig. 1.** Thinking about the future

Are the results of the matriculation exam in mathematics at the advanced level taken scored in the recruitment procedure for the field of study you are considering?

![Graph showing responses to the question about matriculation exam results]

**Fig. 2.** Thinking about the future.
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And how are they presenting their results and arguing their arguments in front of the class forum?

Interestingly, it is in the experimental group – unlike the control group – dominates the opinion that solving challenging tasks is rewarding, but at the same time those students are more likely to abandon of solving the task because they find them difficult.

And it is the students in the control group who more often declare their work until the final solution.

In the context of the method based on student autonomy and posing the tasks, the answers given for the next questions are promising.

The next question relates to one of the most important elements of effective work at the lesson which is postulated by neurosciences: students were asked how they found their work in the group. A great part, following the natural force, is in favor of the effectiveness of this method.
Does problem solving, challenging, demanding new ideas give you pleasure and satisfaction?

Fig. 4. Persistence in work.

Do you often "walk past the problem" if it is difficult and requires your involvement?

Fig. 5. Persistence in work.
Are you looking for a solution for the problem to the effect?

Fig. 6. Persistence in work.

Is it motivating for you to face new challenges?

Fig. 7. Ambition.
It is significant that most of them are students of the control group. The reasons for this should be considered as a result of some specifics of the examined groups. In the control group students are less confident about their performance. And despite the fact that they finally achieve similar results in the form of acquired skills, which is reflected in the school grades, it should be noted that there are more students in the experimental group who are confident in their knowledge, skills and conviction in the rightness of their opinions.

The last part consisted of questions to verify the maturity of the respondents. It was mainly about answering the question as to how much they are aware of how much the result of the matriculation exam depends on them. It is important when determining the course of preparation. Knowing that the student recognizes the importance of his/her preparation and work – and it is this case – you can plan the work so that the student to fully feels that his or her shape and course also depends on him. And he/she also should be aware that has a significant impact on the determined course of preparation. Sharing this responsibility, making student a partner in preparation, encouraging him/her to speak, openness for his/her opinion and incorporating all the elements in his work, enable to create this learning-friendly atmosphere. It should be followed by an improvement in knowledge, skills and – of course – a better result on the exam.

27 persons from the control group and 23 from the experimental group have been surveyed in an anonymous questionnaire. The obtained data was used primarily to understand the specificity of each group. This data complemented picture of the educational situation in both groups. Within the general assumptions adopted as a methodology of preparation for the matriculation exam, the
Are you able to present your solution to the rest of the group?

![Bar chart showing responses to the question about presenting solutions to the group.]

Fig. 9. Social skills.

Do you believe you are able to defend your thesis and argue your point?

![Bar chart showing responses to the question about defending the thesis.]

Fig. 10. Social skills.
Are you motivated to take an effort of preparation for the high school exam?

Fig. 11. Responsibility.

Do you feel responsibility for results of your exam?

Fig. 12. Responsibility.
results of the survey allowed to choose the factors that characterize work in each group, such as the number of tasks solved by the method of working in groups, the number and difficulty of homework, the way of presenting the results of their own work. It is important that the working method determined for the group should be most carefully implemented. Thanks that the result of the experiment will not be distorted by the fact that one of them is preferentially treated. In both different formulas the students of both groups have to be prepared for the exam in the best possible way. The point is to choose the most effective method for a given group.

Second equally important aspect – in the context of educational research – is to show that the most important indicators of educational situation are similar. Just look at future choices, approach for the object, involvement in the class work, motivation and self-awareness. The convergence of these elements will finally evaluate the effectiveness of the selected method. Since we start with a comparable level (the average – arithmetic mean of the experimental group is 2.88 and 3.17 in the control group) we can say that the analysis of the results of the matriculation exam for both groups will be reliable and allow to verify a hypothesis saying: “A tube formula” as a working method including neurosciences postulates, brings better results.

Similarity is also evident when we look at groups in terms of multiple intelligences (H. Gardner).

Please note that looking at a group as a composition of a given type, those 2 groups differ from each other within just 2 percentage points. This confirms the above conclusion that teams are similar. Interesting, however, is a look from a slightly different point of view. Looking at each member separately we are treating the results individually. By examining which type of intelligence is the predominant type, which is indicated as the second one, we receive an interesting conclusion.
It appears that there is no person in the control group for whom the questionnaire of multiple intelligences (W. Sikorski et al., 2015) would indicate the type of mathematical-logical intelligence as predominant. There are people of the profile of which this type appears only as the second or one of many represented on a similar level. In turn in the experimental group, the
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people who represent this type are clearly visible. In the context of the choice of preparation method, this is a good sign. The work needs to be organized with those students as a team of leaders that will motivate the whole group. We will build on them some of our activities.

At present pupils have completed a series of classes devoted to real numbers and algebraic expressions. It was summed up with a test. This was a test of closed single choice tasks. Equal in both groups and carried out at the same time Thus the same conditions have been guaranteed and at the same time, it prevented the exchange of information between groups, which in turn would make the study unreliable.

These are the results, but in reference to them we can say that in the experimental group the problems were generally found easier. It is worth noting that the variance of the tasks’ difficulty, i.e. the product of the percentage of number of students who answered correctly and the percentage of those who gave the wrong answer. In both cases it oscillates around 0.25, which is desired result. With a differentiation power, it indicates that the tasks have been correctly selected. Finally, the arithmetic mean of the scores in the experimental group was significantly higher.

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SUMMARY

Teaching in Polish schools is changing. So far, things have changed in the students’ space. These young people, who sit in desks every year, bring new elements to the school. We, as teachers, can not remain deaf nor blind to this fact. What comes to us with our students is often inspiring, developing, interesting. Our task is to use all the means to reach the students and give them the knowledge and skills, rather than staying on a position that has been set for years, in which they have to adapt to the methods we impose. The results of our research on the brain and the way it learns new content give us clear indications of how we can modify our...
SZUKAJĄCY ŚCIEŻEK UCZNIÓW

STRESZCZENIE

Są ścieżki, które nie prowadzą do gotowych rozwiązań ani nie wykonują za ucznia żadnych operacji, pozwalając na pobudzenie myślenia od postawienia problemu i skierowanie w kierunku rozwiązania. Prowadzenie nie odbywa się poprzez oczywiste pytania sugerujące oczekiwane odpowiedzi. Uczeń samodzielnie myślic..

Słowa kluczowe: neurodydaktyka, neuropedagogika, „dobre pytanie”, edukacja, skuteczne nauczanie