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# The role of experiments and investigations in biology teaching

*Biology is an experimental scientific discipline*
*and, therefore, it is best to learn it*
*by conducting observation and experiments*

Cichy & Żeber-Dzikowska 2000: 14

## Introduction

Biology is not an easy scientific discipline. From the very beginning of its acknowledgment, students come across difficult terminology. For many of them, gaining the basic knowledge, e.g. referring to the structure and functions of the cell, causes many problems. Additionally, students can be easily discouraged if the realization of the subject matter is based only on the methods of teaching that involve providing ready knowledge. "It was confirmed, however, limiting teachers' methods to the provision of ready knowledge results in a considerable lowering of students' activities during lessons and loss of motivation for studying biology; further, it leads to the conviction that biology is a boring subject" (Stawiński 2000: 81).

In order to attract students to the subject and motivate them to work further, apart from the problems that were presented during the conducted classes, investigations and experiments are introduced. They make the young generation more active and, at the same time, they make young people work independently, which supports not only the process of developing their manual skills but also the processes "associated with developing logical thinking and performing […] logical thinking operations, such as: analysis, comparison, disregarding, generalization, synthesis." (Stawiński 2000: 50).

The process of thinking at the beginning is related to formulating hypotheses and problems, and next, to drawing conclusions. It also refers to the consolidation of the recognized terms. Moreover, it enables people to notice the connections between the terms, and finally, makes it easy to understand laws and rules of biology. The realization of the concepts by introducing investigations and experiments also involves the aspect of upbringing since it provides the possibilities to ethically estimate different kinds of investigations in scientific disciplines. At the same time, it makes it possible to create and cultivate the feeling of respect for organisms among young people.

## The analysis of the survey carried out among teachers

The investigations involved 300 biology teachers in lower secondary schools (*gimnazjum*) in the Świętokrzyskie province. They were conducted with the use of such an investigative tool as questionnaire, which was anonymous and included twenty open and closed questions. It also contained questions concerning: sex, work practice, professional career and experience as well as forms of professional development in which the respondents participated.

**Tab. 1.** Data about the respondents*

| Educational stage | Sex | | Professional experience | | | Levels of professional promotion | | Forms of professional development | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | M | A | B | C | a | b | 1 | 2 | 3 | 4 |
| Lower secondary | 279 | 21 | 58 | 121 | 121 | 163 | 137 | 251 | 124 | 128 | 2 |
| % | 93 | 7 | 19,3 | 40,3 | 40,3 | 54,3 | 45,7 | 83,7 | 41,3 | 42,7 | 0,7 |

* The terminology concerns the Polish system of professional promotion and career. The system in the UK, however, involves the following stages: Qualified Teacher Status (QTS) (Q); teachers on the main scale (Core) (C); teachers on the upper pay scale; (Post Threshold Teachers) (P); Excellent Teachers (E) and Advanced Skills Teachers (ASTs) (A).

Professional experience: professional promotion levels – forms of professional development:

| | | |
|---|---|---|
| A- from 6 to 10 years | a- nominated | 1- postgraduate studies |
| B- from 11 to 20 years | b- certified | 2- qualifying courses |
| C- from 20 to 30 years | | 3- courses dealing with Biology concepts |
| | | 4- others; |

Among 300 respondents, there was a vast majority of women, i.e. 93%, and only 7% of men. When the educational reform came into force, there opened the possibility of professional career and promotion. According to this, teachers can get the following levels of the professional promotion:

- trainee i.e. junior teacher;
- contract teacher;
- nominated teacher;
- certified teacher.

In the group under consideration, the nominated teachers are dominant, that is they make 54,3%. There is, however, shortage of junior and contract teachers. Among the respondents, the majority of people reach the professional experience in the periods from 11 up to 20 years as well as from 20 up to 30 years, (i.e. 40,3% each). 58 teachers fulfil this requirement and are included in the range from 6 to 10 years. None of the respondents, however, refers to the work experience period shorter than 5 years and longer than 30 years. The questionnaire also included questions about the forms of the professional development. The majority, i.e. 83,7% marked postgraduate studies among the provided answer options. The most popular among

the indicated branches of science were: natural science, geography and chemistry. 41,3% of the respondents took part in qualifying courses. They named the following courses:

- The estimation of school work quality;
- Teaching the natural science;
- Education for the family life*;
- Courses for examiners;

However, 42.7% of the respondents completed the courses in the range of biology:

- The activating methods for biology teachers;
- Biology and elements of the environment protection;
- Teaching biology in gymnasiums;

The teachers were also asked what kind of studies they completed and what university/high school they graduated from (Fig. 1).

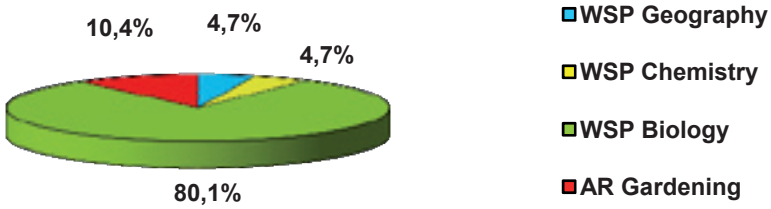


**Fig. 1.** Kinds of completed studies as well as the university/high school from which the respondents graduated

On the basis of the analysis of the received results, it appears that the greatest number of people (80.1%) graduated from WSP and completed biology and 10.4% completed gardening studies at the Agricultural Academy. The smallest number indicated geography and chemistry (4.7% each). Many of the questioned teachers had the qualifications to teach other subjects. Therefore, the questionnaire included the question if they taught other subjects apart from biology (Fig. 2).

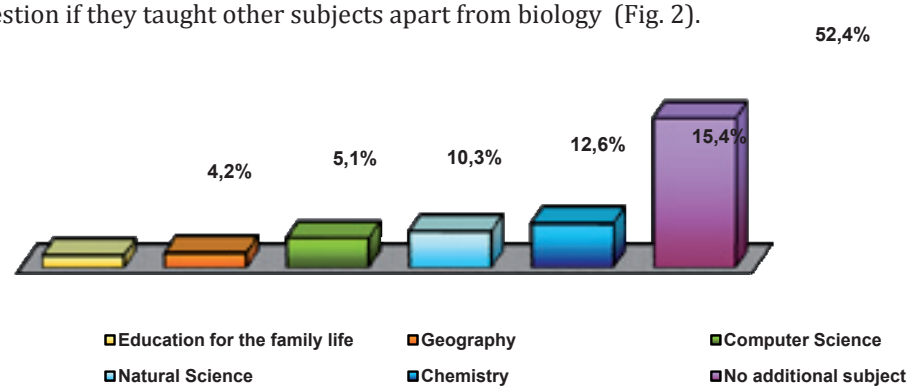


**Fig. 2.** Subjects other than biology taught by the respondents

* In the UK this subject is called 'Personal Health and Social Education'.

Out of the 300 questioned, only 47.6% taught other subjects apart from biology. As the second subject, the teachers, chose to teach chemistry (15.4%), natural science (12.6%), computer science (10.3%), geography (5.1%) as well as education for the family life (4.2%). In the next question, the teachers were asked to provide the author and publisher of the text book as well as the syllabus they used (Fig. 3).

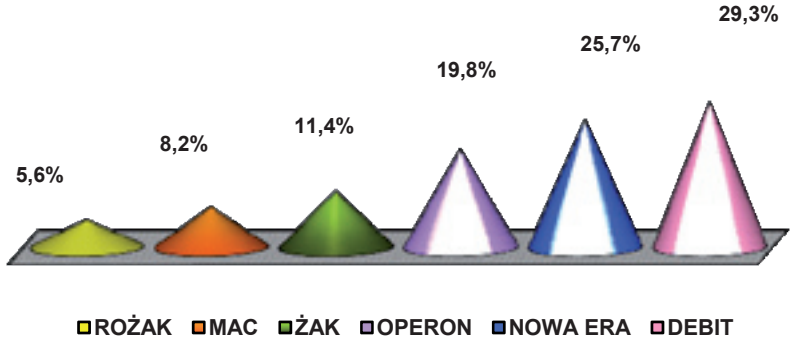


**Fig. 3.** The names of publishers, programmes as well as text books used by teachers

On the basis of the analysis of the received results, it can be claimed that most frequently biology teachers use materials of the following publishers:

- DEBIT – (29.3%)
- NOWA ERA – (25.7%)
- OPERON – (19.8%)

Subsequently, the respondents were asked what methods and strategies they used most frequently during classes.

**Tab. 2.** Methods and strategies most frequently used by teachers

| Indications | Method | | | Strategy | | | |
|---|---|---|---|---|---|---|---|
| | investigative | observational | verbal | operating | emotional | problematic | associative |
| very often | 32 | 156 | 67 | 110 | 13 | 110 | 22 |
| often | 226 | 15 | 18 | 157 | 13 | 13 | 7 |
| seldom | 5 | ____ | 6 | 4 | 6 | 6 | 219 |

On the basis of the analysis of the received results, it appears that teachers very often use observational methods (52%) as well as operating and problematic strategies (36.7% each). They also often refer to investigative methods (75.3%) and operating strategies (52.3%), moreover, they seldom employ verbal methods (2%) and associative strategies (73%). In the questionnaire, there was also a question: "Do you think that investigative methods can be used during every lesson?'

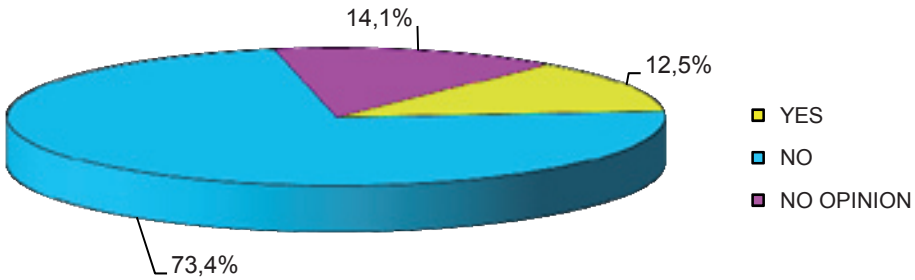


**Fig. 4.** The possibility of using investigative methods

Out of 300 respondents, 73.4% believed that it was not possible to use investigative methods during every single lesson. Only 12.5% agreed that it was possible. The remaining 14.1% did not have any opinion. In the second part of the question, they were asked to justify their answer:

- Not all subjects could be realized with the use of investigative methods (24.7%)
- There were not enough lesson hours during the week, which limited their use, i.e. 29.3% and 46% did not justify their choice.

The next question inquired how often the teachers used investigations and experiments in class.

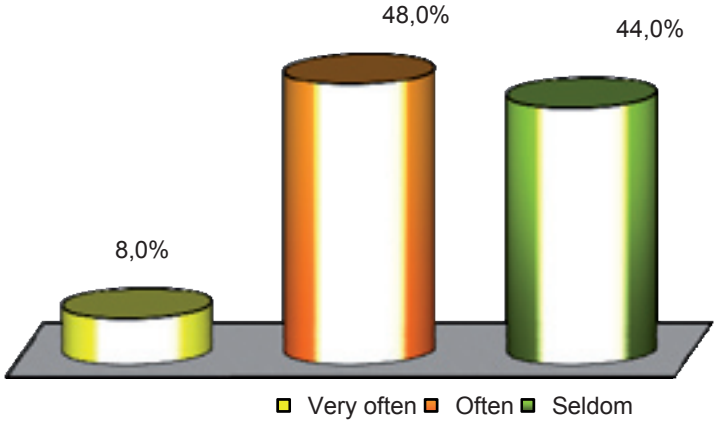


**Fig. 5.** The frequency of conducting investigations and experiments during Biology lessons

On the basis of the analysis of the received results, it can be claimed that 48% of teachers included in the research often carried out investigations and experiments during the conducted lessons, 44% did it seldom, and only 8% referred to it very often. The respondents justified their choice in the following way:

- Investigations and experiments make lessons attractive and allow students to acquire the knowledge better (34.7%);
- They conduct them when it is required by the subject (9.4%);
- Lack of the needed equipment as well as a small number of hours limit the possibility of their use (27.8%).

The remaining respondents, i.e. 28.1% did not provide any justification for their answers. Next, the teachers were asked where they found innovative ideas for investigations and experiments. Four possibilities were indicated:

1. methodology guide books;
2. text books;
3. suggestions in magazines;
4. other.

**Tab. 3.** The sources of teachers' ideas concerning investigations and experiments

| Indications | 1.2.3 | 1.2 | 1 | 1.3 | 1.2.3.4 | 1.2.4 | 2.3.4 | 1 |
|---|---|---|---|---|---|---|---|---|
| Number of people | 94 | 60 | 17 | 45 | 19 | 10 | 12 | 8 |
| % | 31.3 | 20 | 5.7 | 15 | 6.3 | 3.3 | 4 | 2.7 |

On the basis of the analysis of the received results, it can be claimed that teachers look for the ideas for investigations and experiments in several sources. 31.3% indicated that they use methodological guide books, text books and magazines. Only 5.7% of the respondents referred to one of the information sources. They most often selected methodological guide books, i.e. 84.3%, 65% used text books, while 56.7% made use of magazines, not to mention 2.7% of the questioned that employed other sources.

In the next question the respondents were asked to give three examples of investigations as well as three examples of experiments that most frequently appeared during classes they conduct..

**Tab. 4.** Investigations and experiments that were conducted most frequently during classes

| Subject of investigations | Number of people | % | Subject of experiments | Number of people | % |
|---|---|---|---|---|---|
| Influence of light on the process of photosynthesis | 119 | 39,7 | Influence of salinity on beans | 114 | 38 |
| Influence of $CO_2$ on the process of photosynthesis | 67 | 22,3 | Examination of polluted air | 95 | 31.7 |
| Examination of the chemical structure of bones | 89 | 29,7 | Do sprouting seeds breathe? | 49 | 16.3 |
| Detecting the breathing products | 60 | 20 | Influence of the condensed seeds of watercress on the growth pace | 47 | 15.7 |
| Osmosis | 44 | 14,7 | Influence of detergents on the plant growth and development. | 40 | 13.3 |

It can be noticed that teachers most often conducted investigations concerning the process of photosynthesis, i.e. 39.7% as well as chemical structure of bones 29.7%.

Among the experiments, respondents indicated:

- Influence of salinity on beans – 104 people, i.e. 38%
- Examination of polluted air – 95 people, i.e. 31.7%

On the basis of the analysis of the received results, it can be claimed that in all examined distributions of work experience, most teachers value highly the influence of investigations and experiments on the teaching effects, i.e. they indicated 8 in the range from 1 to 10.

The question: 'Do you prepare work cards for the lessons during which investigations and experiments appear?' 62.7% of teachers confirmed this and only 37.3% answered that they did not use work cards. The respondents justified their answers as follows:

- Work cards allow students to work more effectively and individually (22.4%);
- Work cards guide students' work and facilitate the organization of work (17.7%);
- Insufficient number of hours forces the introduction of investigations and experiments in such a form of presentation, and lack of work cards (19.2%);
- 40.7% did not give the justification for their answers.

In the questionnaire, the following question appeared: 'Do students individually form problems and hypotheses to carry out investigations?' The vast majority of the respondents (97.3 %) confirmed it. Only eight teachers answered negatively. In the second part of the question, respondents were asked to write what problems students had concerning individual, and independent formulation of problems and hypotheses. They answered in the following way:

- Differentiation of the problem and hypothesis – 34.8%;
- Expressing the problem in the correct way – 18.5%;
- Expressing the hypothesis in the correct way – 27.9%;
- Expressing the problem and hypothesis in the correct way – 14.8%;

Twelve teachers did not answer that question.

Respondents were also asked: 'Do you ask students to do their homework in the form of simple investigations?' The majority answered that they did, i.e. 77.7% of the respondents. Furthermore, as examples of investigations they asked students to do as their homework, the teachers referred to:

- The influence of light on the process of photosynthesis (16.7%);
- Bean cultivation (14.6%);
- The measurement of pulse and blood pressure (12.1%);
- The fugle (conduction of substances in the plant (6.7%));
- Influence of the condensed seeds of watercress on the growth pace (6.1%)
- Examination of air pollution (4.3%);
- The chemical structure of bones (3.9%);
- The role of saliva in the process of digestion (2.7%);

Four respondents (1.3%) did not provide an example.

The next question inquired about after-school activities conducted by biology teachers.

On the basis of the analysis of the received results, it can be claimed that most teachers conducted additional activities after school (57.7%), such as a biology association – (26.7%), Liga Ochrony Przyrody** – (19.7%) as well as an ecological association – (11.3%). All respondents wrote that during their classes investigations and experiments were conducted. In the questionnaire, there was also a question

** League for the Nature Protection

concerning the equipment of the biology laboratory that was necessary in order to be used during investigations and experiments. Most teachers involved in the research, that is 180 people (60%), wrote that their laboratories were not adequately equipped. The shortages that made it impossible to conduct investigations and experiments are presented in Fig. 7.

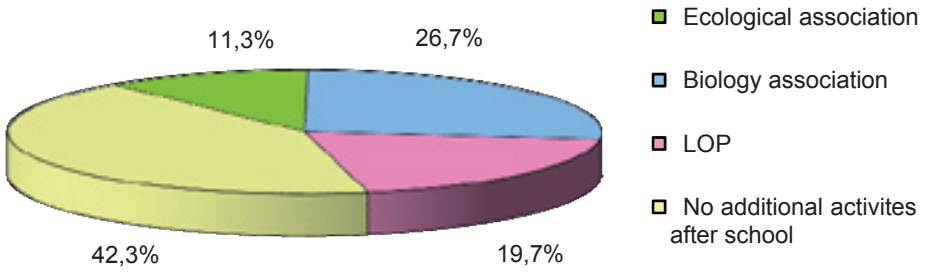


**Fig. 6.** Additional after-school activities conducted by Biology teachers

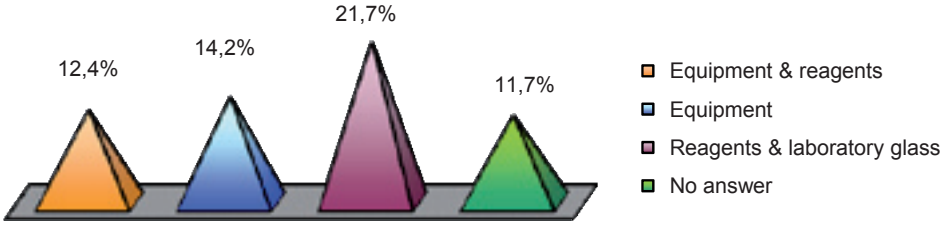


**Fig. 7.** Equipment shortages in the laboratory that make it impossible to conduct investigations and experiments

Among the material shortage which makes it difficult to perform investigations and experiments the reagents as well as the laboratory glass was most often indicated (21.7%). 11.7% of the respondents noted that the laboratory in their schools was not appropriately equipped, however, they did not specify what was missing.

The last question inquired about gaining funds in order to buy necessary equipment and reagents to conduct investigations and experiments.

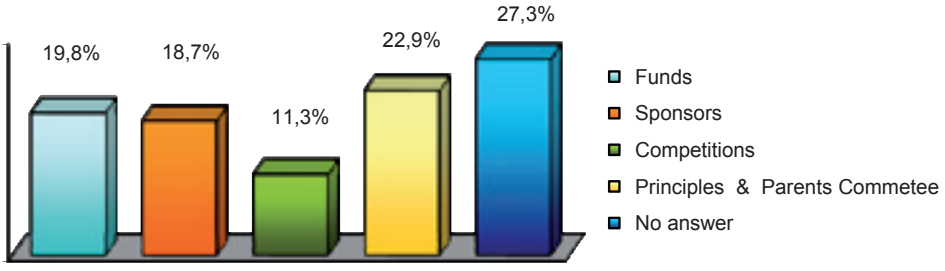


**Fig. 8.** Ways of raising funds for the necessary equipment

On the basis of the analysis of the received results, it can be claimed that the teachers bought the necessary equipment themselves, i.e. spent their own money or asked the principals of the schools to finance the equipment to a certain extent. The smallest number of the respondents received the funds from different kinds of competitions, that is, 34 people (11.3%).

In the conducted investigations with the use of the diagnostic survey, the questionnaire technique was applied. On the basis of the analysis of the received results, it can be claimed that teachers consider the influence of investigations and experiments to be very significant with regard to the effectiveness of teaching. From the information provided by the respondents, it appears that they often conduct investigations and experiments during their classes. Moreover, students independently and individually formulate problems and hypotheses, which additionally impacts the effectiveness of learning the subject matter in question. Unfortunately, the majority of teachers indicated that their biology laboratories are not sufficiently equipped, furthermore, that there is a lack of reagents needed in order to carry out investigations and experiments. This makes the teachers unable to conduct all investigations and experiments which should be realized. However, "most investigations used in biology teaching and learning processes due to their simple character can be conducted in a biology laboratory with average equipment, or even at home as homework" […] Apart from that, in case of an insufficient amount of "the didactic sources being in the teachers' hands, students can work with different material, providing that they would reach the same results, that they would reveal the same biological regularities. In this way, despite differentiated work, students would gain the same appropriate knowledge and the same range of skills. Furthermore, during group work with the use of the same plans of tasks but on different objects, thinking processes become activated and directed to a greater extent. The results would be the opposite in case of the simultaneous work with the homogenic practice material" (Müller, Palka 1988:10,21). A test was conducted among students to check their knowledge, skills and attitudes in the sphere of the physiology of plants and animals as well as to provide data to investigate whether concepts were introduced concerning investigations and experiments, and how this influenced their acquisition.

What students found most difficult were tasks concerning the category of using skills and knowledge in problematic situations. Therefore, it can be supposed that they have problems with understanding concepts of a problem and a hypothesis. Furthermore, on the basis of the results analysis, it is obvious that students have problems with understanding verbal and graphical instruction, which negatively influences the final test results.

On the whole, the conducted investigations and experiments positively influence the knowledge acquired by students. "The most effective in biology teaching are, however, investigative and observational methods. They should create the basis for collecting new facts. (…) The remaining methods play an additional role (and should be used for) of consolidation of knowledge and revision, mainly in the summary stages" (Cichy & Żeber-Dzikowska 2000: 14–15).

Therefore, due to their significant cognitive, educating and upbringing roles, investigations and experiments are a vital element in the teaching process. The te-

achers should pay more attention to the way of their application in order to fully use their positive influence on the teaching effects.

## Conclusions

The analysis of the outcomes makes it possible to draw the following conclusions:

- Conducted investigations and experiments, to a very large extent, influence the effectiveness of Biology teaching;
- Team work in conducting investigations and experiments teaches young people to cooperate, moreover, it can improve their mutual relations;
- Students have problems with differentiation between the concepts of problems and hypotheses as well as with reading verbal and graphical instructions to carry out investigations and experiments, which make it difficult to acquire the knowledge provided;
- Teachers look for ideas for investigations and experiments, moreover, they willingly refer to various sources;
- Biology laboratories are not appropriately equipped and there is a lack of reagents to carry out investigations and experiments; such a situation makes it difficult to conduct them;
- Due to their significant cognitive, educating and upbringing roles, experiments are a vital element in the biology teaching and learning processes.

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## The role of experiments and investigations in biology teaching

### Abstract

The aim of the present study was to establish if the teachers teaching in lower secondary schools (*gimnazjum*) use experiments and investigations in the educational process. The study is based on the diagnostic survey conducted.

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