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PHYSICS EDUCATION

TEACHING ATOMIC PHYSICS IN SECONDARY SCHOOL WITH THE JIGSAW TECHNIQUE

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Abstract. The domain of atomic physics is the field where most research on students' learning difficulties is available. The present study focuses on a simple example concerning the ways in which a highly structured form of cooperative learning-the jigsaw classroom-may work in the field of teaching atomic physics in secondary school.

Key words: cooperative learning, Jigsaw method, physics education, teaching atomic physics.

1. INTRODUCTION

The Jigsaw strategy, developed by Elliot Aronson, is a group-work method for learning and participating in group learning activities. It is a cooperative learning strategy that enables each student of a group to specialize in one aspect of a learning unit to resolve a task or class project [1, 2]. Students are organized like pieces in a jigsaw to form different kind of groups, where each student (piece) must be part of the solution of the overall project (jigsaw puzzle). Each student on the team becomes an “expert” on one topic by working with members from other teams assigned the corresponding expert topic. Upon returning to their teams, each one in turn teaches the group; and students are all assessed on all aspects of the topic. The jigsaw learning technique is a structured, cooperative strategy that avoids many of the problems of other forms of learning in a group. This method has proved highly effective in the distance teaching [3]. This technique and other innovative forms of teaching and learning have been used successfully to promote learning achievements across a range of curriculum areas including narrative writing in small groups [4], problem solving in mathematical tasks [5], or conceptual understanding in chemistry [6, 7], and physics [8–13].

In many countries including Romania, there is a decline in the number of students wishing to continue with physics [14, 15]. A number of factors have been identified by previous researchers as contributing to this decline. It is noted that the study of physics in schools and universities is spiralling into decline as many teenagers believe it is too difficult [16]. It is noted that physics has an image of being both “difficult” and “boring” [17, 18]. Williams *et al.* observed the major general reasons for students finding physics uninteresting are that it is seen as difficult and irrelevant: physics deals with abstract concepts and students find these concepts difficult to grasp [19]. However, results of many researchers who focus on teaching various topics of university physics indicated that conventional teaching hardly improves the teaching of principle concepts of physics [20]. Similarly, experiences in this field suggested that even physics education conveyed by a well-prepared presentation do not give effective results through understanding principal contents [21].

The domain of atomic physics is the field where most research on students' learning difficulties is available. The present study focuses on a simple example concerning the ways in which a highly structured form of cooperative learning – the jigsaw classroom – may work in the field of teaching atomic physics in secondary school.

2. PASSIVE LEARNING

The approach of traditional teaching methods and student assessment leads to students’ passivity. The most common traditional method of teaching, especially in Physics, in the last years of high school is lecture. The causes in many cases are multiple and easy to guess: lack of school laboratories, poor endowment of natural kits for existing laboratories, auxiliary materials, modern means of teaching and assessment (computers, projectors, educational software), sometimes exclusive use of the manual as a means of teaching and not at least, the poor motivation of many students and some teachers to study or to teach Physics. Lack of teaching aids (specialized publications, collections of problems, CDs with videos and virtual experiments, etc.) makes teachers to use in many countries, or high schools, the traditional lecture as basic method of teaching Physics, although it is known that learning occurs only in a very small extent.

Some studies of specialists in pedagogy and educational psychology have shown that [22]:

• The students are aware of only 40% of the time of the lecture (Polio, 1984).

• The students retain 70% of the contents presented in the first 10 minutes and only 20% of those shown in the last 10 minutes (McKeachie, 1986).

The brain processes information as a computer. For a computer to start working, you have to press the start button. If learning is passive, brain power button is not activated and cannot make connections between what is being taught and what the student knows. To “save” the information, he must explain it to the others. The true learning is that which allows the transfer of acquisitions in new contexts. This is best facilitated by the interactive learning. The social aspect of learning was highlighted by Bruner, who introduced the concept of reciprocity in learning, as an incentive of learning [23].

3. INTERACTİVE METHODS OF TEACHİNG AND ASSESSMENT

Theoretical studies and practical applications have shown that the students’ performances in school can become better if the course combines traditional teaching with modern [24, 25]. Thus traditional methods will be partially or fully modernized. In debates concerning how to increase the learning of physics concepts, many researchers claimed that students need to take part in social interaction. In addition, it was underlined that while teaching physics, it is necessary to use methods which utilise instructional activities that students can realize of what they are doing and think of the applications they are carrying out. It is also essential to allow students reflecting their own ideas and prepare an environment giving them a chance to discuss their learning with other students and their teacher.

Traditional lecture may be restored by stimulating students’ interest, deepening students’ understanding, involving them during the lectures, by interrupting it, avoiding an end point. Consequently, the information will be deleted from memory after a longer or shorter period of time, depending on students’ interest on the matter. The Physics teaching process will be differently deployed if we use interactive methods such as those illustrated in Fig. 1.

Enumeration methods are easy; sometimes it is harder to effectively apply them in practice. These methods often involve group work. Students are organized like pieces in a jigsaw to form different kind of groups, where each student (piece) must be part of the solution of the overall project (jigsaw puzzle). The modalities of establishing groups take into account many factors: students’ training, classroom conditions (including school furniture), equipments and teaching aids, students’ interest in studying the subject.

An important factor in the use of interactive methods is the time. The time budget of a class is affected by students’ grouping required time intervals, communicating of the individual or group workload, the distribution of work sheets and teaching aids. Preparing a lesson in which interactive group methods are used, requires more energy from the teacher and a well devised strategy. In addition,

12^{th} form students are very attentive to details, coherence, fluency, but also to mistakes, immediately reacting, often vociferously to the teacher's demands. From these reasons, from commodity, some teachers prefer traditional lecture to achieve the lesson objectives in detriment of the quality and attractiveness of teaching.

During the period 2003–2008 a Rural Education Project: "Implementation methodology and tools for monitoring and evaluation of the Rural Education Project – longitudinal studies I (2005) and II (2007)" was financed in Romania by the World Bank, the Romanian Government, and the rural communities. The aim of this project was the professional development of the primary and secondary (compulsory education) school teachers in rural areas. The purpose of the program was as the teachers, regardless of the discipline/subject taught to become aware of other techniques than those (traditional) which were used almost exclusively in teaching different subjects/disciplines. Physics is one of them. Before the practical application of the new teaching-evaluation methods, the expository activities recorded the highest weight assigned in the lesson's times. In over 40% of the observed lessons, the teacher's discourse lasted 15 or even 30 minutes in the economy of a lesson, demonstrating a traditionalist approach of the role of teacher as the sole owner of knowledge and the central element of the teaching and learning processes. Almost exclusively, the students were traditionally set in a classroom, with desks arranged one behind the other, a format that significantly limits the visual and social interaction between students. The investigation revealed that during a lesson, most teachers do not initiate the reorganization of the classroom furniture, keeping the arrangement of the students the same throughout the lessons. In some cases, the feedback for students in the learning process was non-existent, the work of the teacher focusing almost exclusively on teaching rather than learning. The share of these cases ranged from about 4% of all observed classes. In the initial stage of monitoring and evaluation, according to the first longitudinal study of the project, in almost 70% of the lessons observed there were not conducted any group activities, the frontal type interactions taking up the most important time budget of the lessons. The organization of differentiated activities did not constitute a central element of design and management of the learning activities. There were many situations in which individual activities were organized, but the workloads were not differentiated according to certain characteristics of the students.

The learner-centred interactive teaching has presented and demonstrated the effectiveness of teaching methods applicable to all academic subjects, and the continuous assessment of students has approached, in addition to traditional methods, some complementary methods that lead together to school success, as presented in Fig. 1. Figures represent the share of interactive methods applied in the 393 observed lessons during the project, by the mentor who has worked in the Vaslui County (Romania), among 2005–2008.

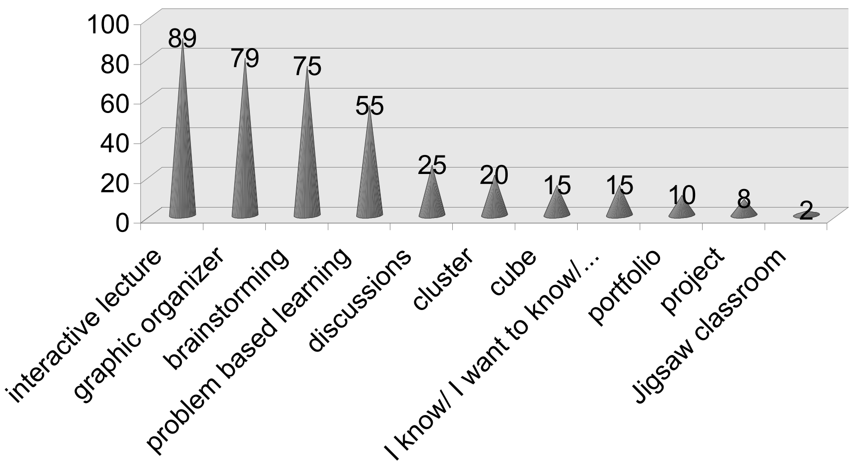


Fig. 1 – Share of interactive methods.

4. THE JIGSAW METHOD

As Nattiv, Winitzky and Dricky express in their research, students are engaged in a higher rate of interaction with their friends when cooperative learning techniques are used [26].

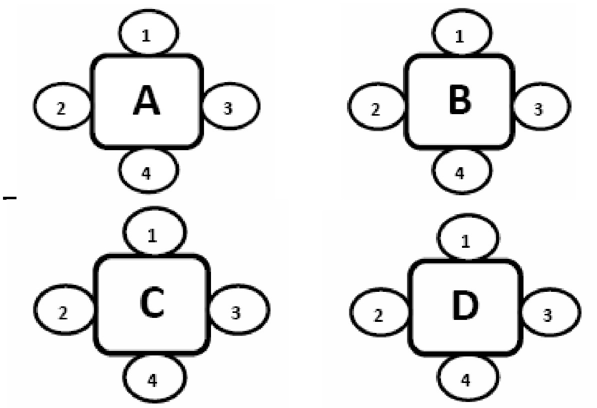
The Jigsaw technique is an interactive physics teaching method. This method can be easily applied with better results in laboratory experiments. Carefully prepared, the method could be very appreciated with high school students and stimulate an academic approach to the proposed theme [27]. From the theoretical point of view, this method has some advantages:

- Boosts students' self-confidence;
- Develops argumentative group communication and networking skills;
- Develops critical, logic, and independent thinking;
- Develops individual and group responsibility;
- Optimizes learning by teaching someone else's acquired knowledge.

The Jigsaw method involves dividing one lesson into sequences (the number equal to the number of working groups) that can be independently treated and that jointly attain the lesson's objectives. The students are divided into heterogeneous groups of 4–6 students. Each student receives an individual worksheet; numbered 1 to 4–6, which shows the workload (the group is called Working Group). This involves an advance planning of the kind of tasks which outline the schedule and what kind of students they are addressed to. Then, the students that have the same number on the form will be organized into groups of "experts" who will actually perform tasks on the worksheets. After a period of time agreed with the teacher, the students will assemble in original work groups, where they will “tell” or show their expert work, in turn, to the colleagues, until the “whole” designed by professor, will be achieved through the contribution of each student group, within the group. Basically, each student works (specializes) in a sequence, while receiving the rest from his colleagues [where each student (piece) must be part of the solution of the overall project (jigsaw puzzle)]. It goes on the idea that working less quantity, but the “qualification” is better.

In order to apply the Jigsaw technique, a piece of modular furniture is necessary to allow the students grouping. It is preferable that students can follow the work of all colleagues in a working device, as proposed in the following arrangement (Fig.2):

Working Groups



Expert Groups

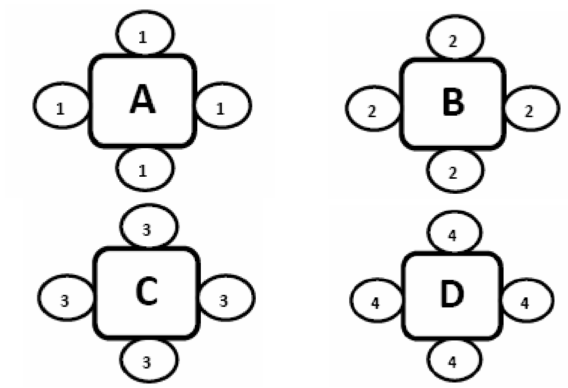


Fig. 2 – The arrangements for working groups and expert groups.

The work sequences must be designed by the teacher so that students could cope with the workload. A surface design could lead to easy tasks for good students and difficult work for weak students. In both cases the results would not be the expected one. Individual and/or group worksheets are indispensable. It is also necessary to appoint a leader ("head") for each working device to coordinate work and to report the team's achievements. It is preferable that the achievements should be marked on sheets of flip chart with markers of different colours to sharply contrast on the flip-chart and to be easily seen in areas more distant from them. The impact of group methods was noted to be greater when the teams assigned for themselves a name and a coat of arms and the competitive spirit is encouraged, as all teams have the same tasks and work. The final results assessment will encourage students to quality of work.

5. A SIMPLE EXAMPLE FOR IMPLEMENTING THE JIGSAW METHOD

A small number of studies suggests learning methods and techniques, which are effective in elimination of misconceptions, which reduce student difficulties and realize meaningful learning. For a Physics lesson, whatever it may be, it is rare to apply a single teaching method. A brainstorm activity is useful to apply before the start of work, as well as the "I know/I want to know/I have learned" method, or a few minutes discussion to reinforce previously acquired knowledge: what is a spectrum, spectral lines, spectral regularities of the hydrogen, the total energy of the electron-nucleus system, etc.

A simple example of Jigsaw method applied to teach atomic physics at an undergraduate level is the following:

• Students no.1 will receive a worksheet printed with the values marked of the mercury spectrum visible wavelengths and hydrogen visible spectral lines whose corresponding wavelength values have not marked. Most effective would be for the students to actually photograph the spectra of mercury and hydrogen and reproduce them in print with a color printer. The students who form the first group of specialists have to measure the wavelength values of hydrogen atoms spectral lines.

• Students no. 2 will receive a worksheet where the values of the wavelengths of visible lines forming hydrogen spectrum are given (see the first column of the Table 1). They have to calculate the corresponding photon energies in eV.

• Students no. 3 will calculate the values in eV of the photon energies for the first four spectral lines of the Balmer series, according to Bohr's model. The worksheet will contain the hydrogen ground state energy E_1 [eV].

• Students no. 4 will calculate, according to Bohr's model, the Rydberg's constant corresponding to the first three lines of the Balmer series, that can be observed in the visible spectral range by simple methods. The worksheet will contain these wavelengths values (see the second column of the Table 1).

After they have finished working in groups of experts, they will meet in working groups, where each student will present the findings of work in peer groups of experts, as follows:

Students no. 1 will show to colleagues that the hydrogen spectrum in the visible spectral range contains three lines: the first of red colour, the second green-blue, and the third violet. If their work is correct, the measured wavelengths of these three lines must be within errors, the values given in the second column of the Table 1.

Students no. 2 will show the calculated energy values (eV) of the photons corresponding to the wavelengths of the first four line of the Balmer series given in the first column of the Table 1.

Students no. 3 will show the calculated energy values (eV), according to the Bohr's model, of the photons corresponding to the first four lines of the Balmer series, considering that the ground state energy for hydrogen is $E_1 = -13.6$ eV.
If the results are correct, the corresponding calculated values of the group 2 and 3 must be the same within errors.

Students no. 4 will show the calculated values according to Bohr's model, of the Rydberg's constant corresponding to the first three lines of the Balmer series.
If the results are correct, the three calculated values for the Rydberg's constant must be the same within errors ($R = 1.097 \cdot 10^7$ m^{-1}).

Table 1

The wavelengths in nm of the experimental values λ_{lit} of the hydrogen in the visible range and the observed values λ_{obs} by simple methods

Line	λ_{lit}	λ_{obs}
H_α	656.28	654
H_β	486.13	488
H_γ	434.05	435
H_δ	410.17	

Finally, each group will do a summary of all presentations, embodied through a graphic organizer or concept map which will be presented by the group leader, using frontal presentation. As homework, the students will have to do an essay to establish the connections between their information and that received from colleagues, to make an overall composition whose purpose is mentioned in the article's title.

6. CONCLUSIONS

The entries can be very good pieces in the portfolios of students who are interested in Physics. With a minimum of teaching aids, the students can learn an important amount of atomic physics knowledge:

• The radiation from hydrogen, as well as other atoms, is emitted at specific quantized frequencies.

• The atoms exhibit stationary states whose energy has definite values. These energy levels have negative values.

• Atom radiate energy due to transitions from a higher energy level to a lower energy level. In this processes are emitted photons of radiation, considering the energy conservation low. The energy values of these photons correspond to the wavelength values of the spectral lines observed in the simple emission spectra.

• The wavelengths of hydrogen emission lines observed in the visible spectral range by simple methods, allow calculating according to the Bohr's model, the Rydberg's constant. The value of this constant is very important for metrology [28]. The Bohr's model can predict with a good approximation this value.

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