EXPERIENCES IN TEACHING GAME THEORY IN THE HIGH SCHOOL

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ABSTRACT

Investigations among primary and secondary school students indicated that young people know neither the concepts of game theory, nor its application to different sciences. This motivated us to start teaching game theory at an elementary level for three groups. According to our experiences the students were open and active participants mostly due to their emotional relationship to concrete life situations. In addition to traditional games we discussed some social dilemmas and cooperation-type games. At the end of the course the interest shown by the students and the knowledge acquired by them were analyzed by a questionnaire. In the future a more detailed teaching of game theory is planned in study circles to overcome the limitations of regular courses.

INTRODUCTION

The idea of teaching game theory in high schools has been continuously emerging for several decades due to books [1], [2], [3], [4] and articles emphasizing the importance of the concepts of game theory in the explanation of biological and economical processes and of human behaviour. Despite several promising initiations in Hungary [5], [6], [7] and abroad [8], [9] game theory does not belong to the standard topics in the high schools. Recently this activity is mainly limited to special interest groups.

When planning the teaching process, the importance of the structured knowledge and its relations to other topics (like biology, ethics and social sciences) are taken into consideration. As the distorted latent knowledge elements can prevent the acceptance and the integration of new information [10], [11], [12], [13].

The first impressions indicated that the students' knowledge about game theory is generally poor and incorrect. The quantification of these investigations are detailed in the next section. The subsequent courses of game theory are extended by playing several types of games, meanwhile the student reactions are also quantified by questionnaires. In many cases the introduction of game theory is preceded by a short discussion of decision theory when the students' reactions are investigated. In this work I report on the student's behavior during different "games" and also on their opinion developed by the end of course.

PRELIMINARY KNOWLEDGE

In order to explore students' knowledge about game theory I designed a questionnaire. The first series of questions are related to the concept itself, more precisely, to relationships between game theory and toys, gaming, gambling, role play, round robin games in sports, etc. The second series of questions are addressed to clarify its application/relevance in

mathematics, physics, sociology and economics. In the questionnaire the students have to mark "yes" if they find existing connection(s).

These questionnaires were filled by 35 primary school students and 57 high school students. The statistics are shown in Fig.1. Accordingly, the respondents indicated the connections between game theory and concepts related directly to different types of games. All the students found a link between game theory and some branches of mathematics, however, they knew nothing about the application of game theory in biology. At the same time they marked connections to physics, sociology, and economics with a decreasing portion of responders as denoted on the right panel of Fig.1.

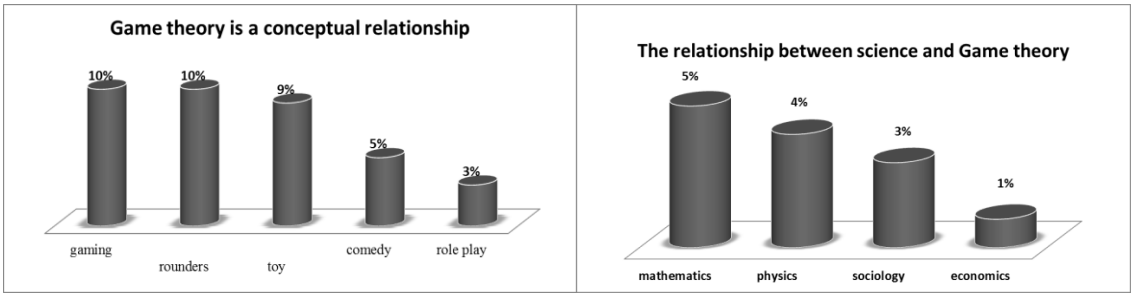

Fig.1. Mapping relationships; Left panel shows the portion of responders who found relationship between game theory and the corresponding items. Right panel illustrates the portions of students marking the connections.

In the interpretation of the above results we should keep in mind that young people have no clear picture of the structure of sciences and the rising importance of multidisciplinarity. It is conjectured that most of the marked connections are denoted by students who are familiar with physics and mathematics. The quantitative analysis of the latter conjecture can give us arguments supporting the importance of teaching natural sciences in high schools.

BEHAVIOR IN A PARTY

The second investigation was performed to study the students' behaviour when they participate in a party and face the quantification and consequences of their decision.

In the basic situation the students have to assume that they are going to a party in which a part of the consumption is covered by the ticket. When showing up the ticket, they can add offerings to the organizers who divide it among all the guests equally. The question was: What do you bring with yourself?

The second situation was similar to the previous one. The only difference is that now the organizers bring your offerings to the table at which you sit, and during the evening they serve the table company with this. The question is the same: What do you bring with yourself?

In both cases three options were distinguished: 1) nothing, 2) cheap, or 3) expensive one. The results in both cases are summarized in Fig.2. The statistical analysis is based on questionnaires filled out by 57 people who received a short time for marking their answer that was not allowed to be modified later.

The left panel of Fig.2. illustrates that students chose the three options with almost equal frequencies in the first case. On the contrary, the portion of altruistic students increased significantly in the second case. Simultaneously, the frequency of parasitic behaviour decreased.

Discussing the students' choices allowed us to explore the valuations that motivated the students to choose one of the possibilities. At the same time the students recognized the possibility and advantage of systematic and quantitative analysis of situations. This was a fruitful first step in the process of teaching game theory.

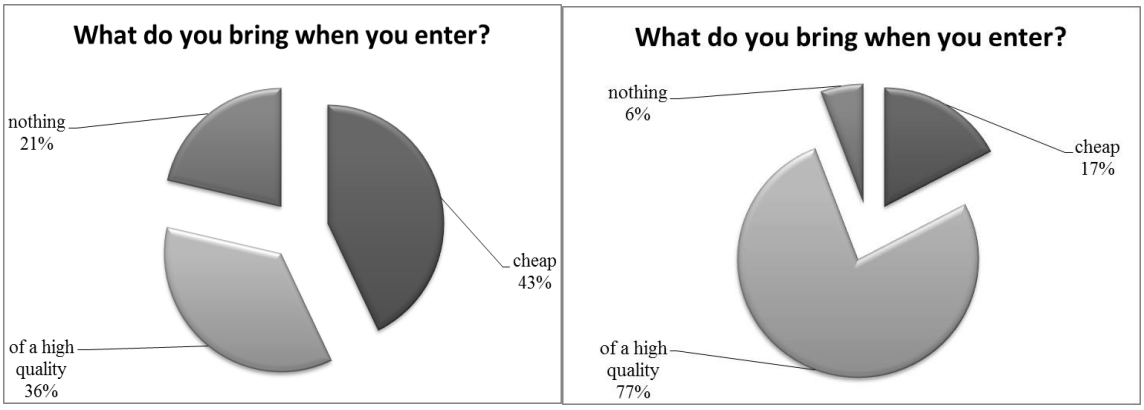

Fig.2. How unselfish young people are? Left panel: first situation; Right panel: second situation

The most important message of the present example is related to the social dilemmas [3], [4] when the individual and common interest dictate opposite choices. Namely, selfishness prefers nothing to any other options while all the members at the same table benefit if they give something to the public goods. The latter choice is enforced by the possible punishments and rewards in the same community during the party. Such situations and methods to maintain the cooperative behaviours are well discussed in the literature of evolutionary game theory [3], [4], [14], [15].

CHEATING

The present situation is adopted from the students' lives in the school when the wrong decision can be avoided routinely by following one of the behavioural schemes developed after a sufficiently long learning procedure that is recorded in the right hemisphere of the human brain [10], [14].

The students are requested to imagine the following situation: Exam is coming and you are not prepared. When you enter the room, a classmate gives you a cheat sheet, which contains his name on it. He asks you to give it back at the end of exam, because he will need it later. If the teacher catches you cheating, he takes it away, and you can continue the work. Each student's dilemma: Are you going to use the cheat sheet?

In the second version of the previous experimental game the basic situation is slightly changed by setting the consequences more serious: If the teacher catches you cheating, he takes the cheat sheet away, and sends you to the director's room.

The third round contains the prospect of an even more severe punishment. If the teacher catches you cheating, takes it away, and sends you and also the owner of the cheat sheet to the director's room. In all three situations the students should answer the same question mentioned above. In these analyses 74 people participated and the results are demonstrated in Fig.3.

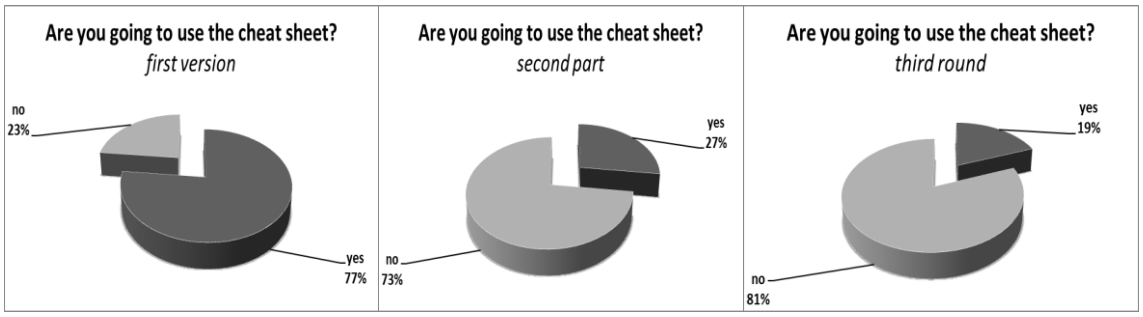

Fig.3. How responsible are young people?

The above results are also consistent with those described in the literature of evolutionary game theory and human behaviour. Recently, for the experimental investigation of the human behaviour, the personal reactions are considered by creating a real-life situation by playing suitable games. Consequently, the spirit and approaches of physics can be well recognized in these multi-disciplinary research fields. Namely, the general laws are approximated by mathematical formulae, mathematical tools are used to extract quantitative consequences and general relationships that are contrasted with experiments.

TALE AND MATH

After playing the above games and discussing their consequences as well as the direct applicability of the results in our every-day problems, the students accepted the relevance of mathematics. Waking up their interest, they become active in learning math. As a result, the students mastered the basic concepts of game theory: players, decisions; possible strategies; decision chart, payoffs, quantification of payoffs, and dilemmas. The possible modes of representation applied: the matrix and graph forms of representation were introduced in normal and extensive games. Examples used in the class prepared for high school students were drawn from book of membership clubs [16].

It is observed that the quantitative investigation of situations in life has improved significantly. Students apply the matrix form with pleasure. Although the analysis of a fable is time-consuming, it is instructive and enjoyable. One example for this is the well-known fable: The fox and the stork. Fig.4. shows the transformation of this tale to the terminology of game theory.

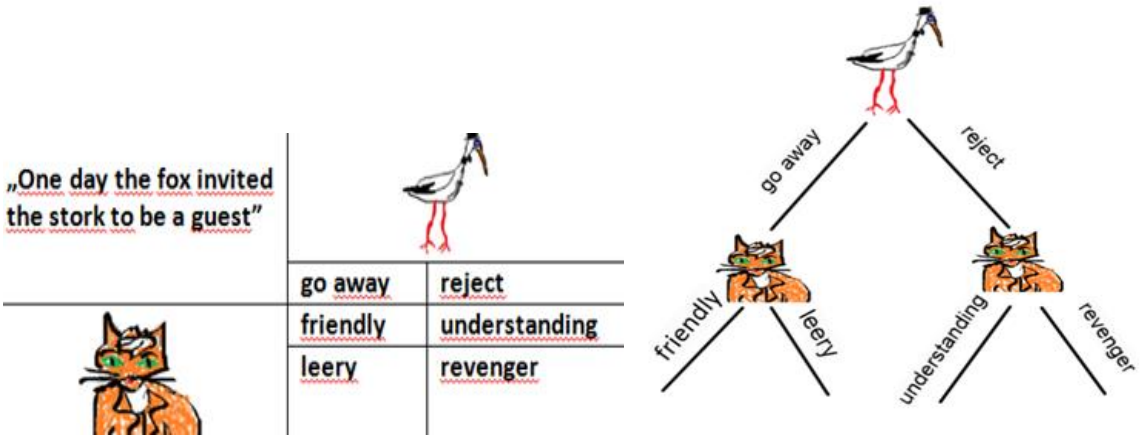

Fig.4. One fable in matrix and graph form

In addition to this advantage, the game theory gives us possibilities to extend their mathematical knowledge.

The group that took part in the survey faithfully reflected the displayed standards of social behaviour. Increasing the penalty appears free-riding dilemma on the game theory [7].

Beyond the present theme for processing I found a lot of other interesting ideas to help the kids in understanding. In lessons the students were involved in real interactions, and then the situations was analysed, interpreted. The life situation affected the teaching and the social relationships, and the analysis of literary works equally [1].

In accordance with the summary measurements the students learned a significant part of the processed topic. Because the durability of knowledge is influenced also by the experience, such processing of science provides a good opportunity for experience-based learning [2]. The topic contains mostly unknown parts. Data processing does not make a significant difference in topic processing.

GENERAL IMPRESSIONS

The reactions of the students demonstrated clearly that they enjoyed the participation in these types of lessons where they were involved in real interactions as well as the subsequent mathematical analysis and interpretation of situations they experienced.

Here I have to mention the reaction of one of the students who participated in these lessons. A participating student told me the following words about the work: *"During this time, we learned how to address certain situations by applying a set of rules. It is noteworthy that these things are "standards", because people often do not consider and decide on their own and others' positions and the opportunities under the current momentary mood. And so perhaps we could be more effective people."*

The above opinion reflects clearly the interest of this young generation in understanding problems related to fairness, cooperation, cheating, and exploitation. They easily understood the necessity of strategies (punishment, reward, reciprocity of both the cooperative and defective strategies in repeated games) that support the maintenance of cooperativity in the human societies.

It was nice to see in the classroom how easily the students applied the game theoretical concepts for the analysis of problems they were deeply involved (e.g., the divorce of their parents).

Depending on the high school's ICT equipment, some tests of simulations could also be implemented. If the students' background knowledge in mathematics are satisfactory, some situation analysis is possible, too. In the good case the social sensitivity of the students changes positively with the help of the tests and concrete examples.

CONCLUSIONS

Teaching game theory in the high schools is enjoyable for both the students and teachers. The combinations of playing games with subsequent mathematical analysis are found to be extremely useful. The students easily learned and applied the basic concepts of game theory.

Additionally a relevant increase in the reputation of the quantitative analysis (in contrary to the hand-waving discussion) is observed. The variations in the viewpoints and opinions of students are accompanied with an improved activity in lessons of mathematics, physics and other natural sciences.

One of the main aims of teaching game theory is to promote the social integration of students by the enforcement of keeping social norms. Recently we are at the beginning of utilizing the concepts and results of game theory in the education in order to increase the level of cooperative behaviour in the human societies.

In the light of the above advantages we wish to continue these efforts. The goals involve improvements in methodology, to find further games and simple mathematical methods that can be studied in high schools.

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