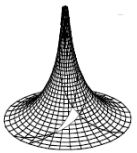

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Manipulatives and semiotic tools of Game of Go as playful and creative activity to learn mathematics in early grades in France

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Abstract. This research develops resources to teach mathematics in French primary school by using the game of Go. A group of searchers, teachers and go players meet at university to produce teaching resources. These resources are implemented in the classroom. Then the group evaluate this implementation and improve the resources. The aim of this classroom research is to study the opportunities of the game of Go to learn mathematics and to propose a teacher training course to implement the game of Go in French primary schools in accordance with the French syllabus. Game of Go appears as a manipulative and semiotic tool to learn mathematics at primary school.

Key words and phrases: go game, semiotic representation, manipulative, primary school.

MSC Subject Classification: 97D50, 97U60.

Theoretical framework: Double transposition and registers of representations by using game of Go

Using the terminology of Chevallard's anthropological theory of didactics (Bosch & al. 2006) we consider that the Strasbourg Go Club (Strasgo 2019) is an institution that

produces the knowledge of the ways to play the game of Go. In the research group, a post-secondary mathematics teacher, member of the Strasbourg Go Club and a secondary school teacher, captain of the French Go team, bring this knowledge about the game of Go. French primary school is another institution where the mathematical syllabus is taught. About ten primary school teachers and a university didactician bring this knowledge about the teaching of mathematical syllabus. We study the double transposition of the knowledge of game of Go and of the knowledge of the mathematical syllabus in the French primary school. Using the praxeology theory (Bosch and al. 2006), we study different teaching tasks offered in classes, the way of doing these tasks and how this way of doing is justified, here from the point of view of the game of Go and from the mathematical point of view.

We use the problems offered by the game of Go as a new approach to learn mathematics because we assume that in this context "pleasure, elation and satisfaction occur" (Debellis & al. 2006, p.134).

Furthermore the material used in game of Go (board and stones) enables to work in a new register of representations. "Mathematical comprehension begins when coordination of registers starts up. […] Mathematical thinking processes depend on a cognitive synergy of registers of representation" (Duval 2006, p.126). We assume that the context of the game of Go will help to learn mathematics.

Methodology: Action research in IREM and didactic engineering

This research takes place in an IREM (Research Institute of Mathematics Teaching): "Independent from, but close to mathematics departments, these university structures welcome university mathematicians, teachers, teacher educators, didacticians and historians of mathematics who collaboratively work part-time in thematic groups, developing action-research, teacher training sessions based on their activities and producing material for teaching and teacher education" (Artigue & al. 2019 p.13). We use the methodology of didactic engineering: "a phase of preliminary analysis and design, a phase of teaching experiments, and a phase of retrospective analysis" (Margolinas & al. 2015, p.901). Once per month the research group meets with the following phases: playing and learning the game of Go, reporting about the experiments

in the classes and sharing produced resources, reflecting on the experiments and conceiving new experiments to implement before the next meeting.

To analyse the teaching experiment we use the double approach methodology (Robert & al. 2005): "This method proposes a twofold approach: on the one hand – in a didactics-centred approach – we developed a general frame-work for analyzing teachers' practices taking into account two elements that are very closely linked, students' activities and the teacher's management of the class, [...]; and on the other hand – in a cognitive ergonomics approach – we have considered the teacher as a professional who is performing a specific job" (Ibidem p.270).

Examples of details of the experiment

Short presentation of the game: First let us introduce shortly the game of Go. It is a strategy game for two players; one player has the black stones and the other one the white ones. The player with the black stones begins the game and more generally all the exercises. The Go board is a grid of lines called goban. One player takes his turn to place one stone on a vacant point of intersection of the board. The stones are not moved. This player captures a stone or group of stones of the other colour when they are surrounded by his stones on all orthogonally adjacent points. At the end of the game, the winner is the player who has the greatest number of stones on the board. We adopted the variations of the rules of the Game suggested by the Strasbourg Go Club (Strasgo 2019).

The research group: The research group gathers varied members: a university mathematician (former searcher in pure mathematics and at the present time searcher in mathematics didactic), a post-secondary mathematics teacher member of Strasbourg Go club, a secondary school teacher captain of the French game of Go team, and about 10 primary schools teachers (with classes from grade 1 to 5 represented). Some teachers are members of Strasbourg Go club that informed them about the creation of this research group. They have practised Go game at school, either in a club outside the classroom, either by experimenting on their own with their pupils during compulsory school time. Other teachers were informed through traditional information net (institutional net of educational authorities) and some of them have no knowledge about Go game. Some of them did not follow mathematics initial studies. This heterogeneous sample of teachers does not claim to be representative, in particular because it is based on volunteering.

Learning of game of Go knowledge:

In the first meeting of the research group the aim of the game introduced to the teachers and a final position is displayed. The discussion is about how the pupils compare the two numbers of stones. Then the capturing rule is explained. Different exercises are shown: complete the surrounding of the white stones, show the surrounded group.

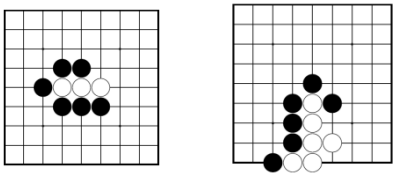


Figure 1. Complete the surrounding.

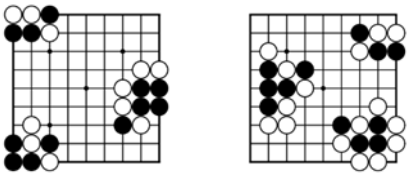


Figure 2. Show the surrounded group.

The winner is the player who has the greatest number of stones on the goban at the end of the game.

Learning of mathematical knowledge:

The official French syllabus for the three first years of primary school (6 to 9 years old) indicates: "Contextualized problem solving: counting collections, measuring quantities, identifying a rank in a list, predicting the results of actions related to collections or quantities (comparing them,…" (Ministry 2018, p.24). Counting procedures are proposed, by grouping stones in rectangles or lines without necessity of counting or by enumerating. Grouping the stones can offer representation registers (Duval 2006) for different mathematical notions. Grouping in lines of same length can be a representation register of multiplication understood as the iteration of an addition (for example 20=5+5+5+5). Grouping in a rectangle can be a representation register of multiplication understood as the product of two magnitudes (for example 20=5x4). Grouping in 2 lines of 5 stones or in 1 line of 10 stones can be a representation register of decimal number system. Teachers have experimented these activities and testify that the pupils get involved and the representations by stones help pupils in difficulty for counting.

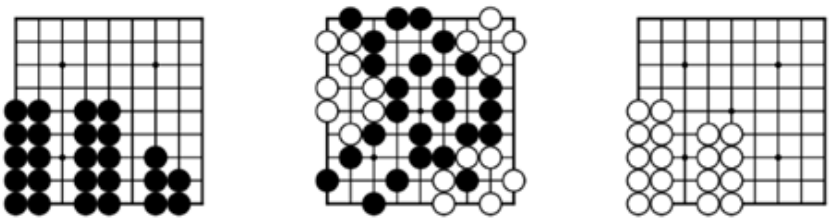


Figure 3. Comparing without counting

Solving go exercises will enable to work on further mathematical skills. It is common in France to introduce the topic of coordinates using the game “battleship”. The game of go will provide a more challenging way to approach the topic. In the following exercises, the pupils will have to solve a Go problem: black plays and captures one or several white stones. They’ll also have to learn how to communicate their answer using coordinates.

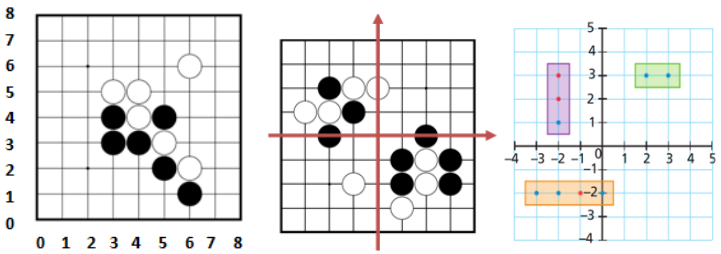


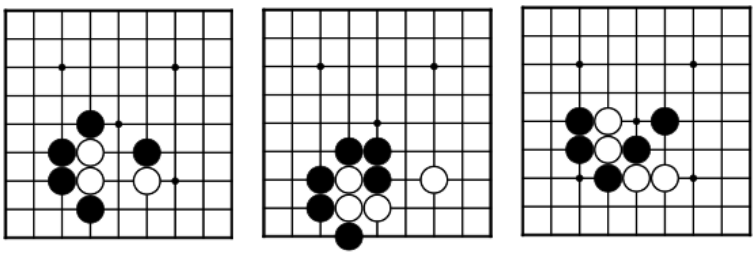
Figure 4. Coordinates exercises

These exercises use some basic Go knowledge (capturing stones). They’ll help the teacher introduce a new mathematical topic (coordinates) providing graded exercises according to the age of the pupils. « Communicating », one of the six main skills developed in the teaching of mathematics (Ministry 2018) is involved in these exercises.

Reasoning: another of these six main skills will be trained when the difficulty of the Go problems is increased. Different types of reasoning coexist in primary school (Cabassut 2005). Heuristic reasoning will enable the player/pupil to solve a Go problem.

In the following exercises, black has to capture one white group (of one or several stones) in two moves. It means that he’ll place a first stone. White will have the possibility to answer. With his second move black will capture the white stones.

The pupil will first have to identify his target. If black can capture in two moves, then the white group must have two liberties. Then he'll have to consider both options : « if black plays here, then white will answer there… ». Will black be able to capture the stones next? The white group must have only one liberty left in order for black to be able to capture with his second move.



Fiureg 7. Black plays and captures a white group in two moves

Many other topics can be covered using the game of go including geometry and geometrical magnitudes (length and area). Are the stones displayed forming a line? Measure the area and perimeter of a territory surrounded by stones. Show the symmetrical axes of the shape, etc.

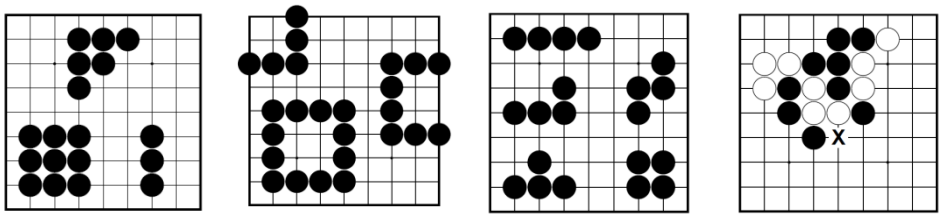


Figure 8. Shapes, magnitudes, fractions

Data organization can be worked by organizing a Go tournament: how the different games will be planned and how the results of the games will be managed. Fractions can be approached by go problems as well: "Which fraction of the white stones is captured when black plays at X?". Manipulating the go material (grid and stones) will also enable the teacher to give more concrete exercises to the pupils, especially those facing more difficulties.

Feedback of teaching experiments:

Experiments show that different parts of the syllabus are being worked on, as for example in grade 1, addition (complement to make 10) or lines (horizontal, vertical, diagonal). Pupils seem to easier represent the notion in the Go context that looks familiar.

Some teachers consider general benefits of the game of Go. The moral rule is important: do not cheat when playing. Pupils get confidence thanks to the game of Go. The most skillful ones are not always the best in mathematics. Pupils play with each other at the game of Go and are used to switch game partners. The social life of the class is improved.

Teachers notice the pupils' motivation to play because the rules of the game are easy to understand. Some pupils who experience languages difficulties (because French is not their mother language) find it easier to express themselves during the game.

Two modalities of work: either a couple of pupils playing with the game of Go or a collective discussion by using the classroom board. To work the situations with the classroom board helps a lot the pupils with difficulties. The difficulties can be on the game of Go side to understand the rules or on the mathematical side to understand a mathematical idea.

Figure 9. Players' couple

Figure 10. Classroom board

Sharing of materials and resources:

It could be activities where only the Go game material is used without playing the game of Go. A teacher adapted the counting stick (Millet & al. 2007, p. 138) to learn multiplication tables with labels representing the numbers with rectangles of game of Go stones.

Figure 11. Go stones representation for the multiplication table of 3

A software (Strasgo 2019) is available to practice at home against an artificial intelligence.Some teachers use videos on Dragon or Manga stories to motivate pupils and bring cultural context (Wikipedia 2020).

Results and conclusions for teaching and teacher training

With the first experiments it is possible to move the game of Go from voluntary activities outside the classroom to compulsory activities inside the classroom. For the game of Go knowledge, the experiments show that it is possible to learn adapted game of Go rules and to play game of Go in primary school. The progression proposed to learn the rule of game of Go has been well adapted to the variety of class situations. From the pupils' point of view the experiments show that motivation, pleasure, social behavior are developed through game of Go activities. For the mathematical knowledge many parts of the French syllabus of primary school can be taught through the use of game of Go. The game of Go brings interesting registers of representation and the change of registers is a good way to understand the concepts and the procedures. In a next step different didactic engineering in different levels of the French primary school will be set up to test hypotheses on the joint learning of knowledge on the game of Go and mathematical knowledge of the class syllabus in the spirit of the first thesis on this topic (Haye 2019).

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