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VARIATIONS OF A GAME AS A STRATEGY FOR TEACHING SKILLS

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Introduction

The mathematics group of the Science Teaching Department of the Weizmann Institute has developed a curriculum for junior high school. As part of the curriculum materials, mathematical games have been integrated into those chapters which deal mainly with basic skills, in order to break the routine and increase motivation.

One of these chapters deals with beginning algebra, algebraic expressions and substitution, and the accompanying game is called "The Steeplechase". In this article we describe a strategy for teaching this chapter using various modifications of the game appropriate to the students' progress, from the opening lesson through exercising to mastery. We also discuss how the game can be modified to suit different populations and ability levels. Finally, we describe our experience of the use of the game in its various versions in the classroom.

Various forms of the Steeplechase

In this section we describe several versions of the original game - "The Steeplechase" (Friedlander, 1977). In order to understand the different versions we need to bring first the game as originally conceived and published.

The original game

The game is designed for two to four players. It is played on a board with a track divided into strips, in each of which there is an algebraic expression or instruction (see fig. 1). In the middle of the board there are three piles of cards: 18 (blue-backed) cards on whose face the numbers 1 to 6 are printed (3 of each card); 18 (yellow-backed) cards on whose face the numbers -1 to -6 appear (3 of each card); 2 (green-backed) cards with zero on the face. Each player has a counter.
The cards are placed face down on the appropriate places on the board. Each player places his counter at "GO". When his turn comes, a player chooses a card from the top of that pile which he thinks may be most to his advantage. He substitutes the number into the expression written on the strip at which he stands, and the number he obtains determines his move:

forwards by that number of places if the number is positive;

backwards by that number of places if the number is negative;

zero movement if he gets zero.

If he obtains a meaningless expression he returns to "GO".
If he lands on a place carrying an instruction, he obeys it at once.
The first player round the track twice has won.

Insert Figure 1 about here

The Steeplechase - as an opening lesson

The main reason for developing the original game was to exercise basic algebraic skills. But feedback from schools suggested that the game could be used for additional purposes. Thus reports from different schools indicated that the game is a good opening to the topic and can be introduced even prior to any formal teaching of the topic.

Examples of two cases of feedback which we received are the following:

(i) One teacher reported with some excitement "I was all ready to start teaching ("open phrases") - but my students stopped me and claimed they already knew the topic. To my surprise I discovered that they were right. They had played "The Steeplechase" with another parallel group, who were a little in advance. This second group had already studied the topic and had played in order to achieve skill mastery. My students understood and grasped the concept "open phrase" by practising substitution with their friends and achieved mastery without a formal lesson.

(ii) Following the experience described in (i), we decided to experiment with the game as an opening lesson in another school. All the 7th graders in the school were given the Steeplechase prior to studying the topic. The students were told to substitute the number on the card they picked in place of the letter on the board. (The words "variable" and "open phrase" were not used.)
The students started to play with excitement, but soon a problem arose.
"What is 2a - 3?" "What is "-2n?" The problem was solved by explaining that 2a - 3 is 2•a - 3 and -2n is -2•n. The game continued.
This minor hiccup in what was otherwise a successful beginning, suggested the first variation on the original game. We added the dot to signify multiplication between the number and letter in all the relevant expressions on the board.
The insertion of the multiplication sign is sufficient in many cases, but we found that weak students have another difficulty altogether. For them some of the algebraic expressions are too complicated: they find difficulty with the absolute value and expressions involving fractions.
In figure 2 we give an example of a board suitable for an opening game for such students.

Insert Figure 2 about here

In place of exercises

If one begins with one of the variations described in the previous paragraph (or with a conventional lesson/exercise scheme) and wishes to continue to exercise towards mastery using a game, then the original version is suitable for most students. However, brighter students, who have already used the game as an introduction, need a new challenge, otherwise the game lacks sufficient motivation and thus defeats its own purpose.

To change the algebraic expressions on the board as we did above, only this time to "harder" ones, is neither sufficiently challenging nor does it relate to a reasonable educational objective. However, we can change the rules of the game, in such a way as to encourage the brighter student to plan his strategy.

The change of rules we used was the following:
Each student gets 4 cards, 2 with positive numbers and 2 with negative numbers. At each turn he must decide which card would serve him best. After substituting the number on the chosen card and moving accordingly - he replaces this card on top of the correct pile on the table and takes another card from the bottom of the same pile. If he decides that zero would be his best choice, he may use more than one card, the sum of whose numbers is zero (if he has such). The cards are returned to the appropriate piles and new cards are taken from the bottom of the same piles.

This version enables the planning of several steps in advance, which appeals to bright students and exercises strategic thinking.

Widening the field

Another possibility altogether, which can be adapted both for strong and weak students is to change the expressions on the board to two variable expressions. This extends and enriches the topic at the same time as providing further exercise.

For strong students a board like the one in figure 3 is suggested.

Insert Figure 3 about here

In this version, the game includes 4 piles of numbers so that for each variable there is one positive pile and one negative pile. Each player chooses one card for x and one for y when his turn comes. The remaining instructions are unchanged.

Here, the complication of having to consider the possible outcome of the substitution of two variables, is sufficient challenge to make the game interesting even to bright students. For weaker students, the expressions in figure 3 are too complicated, but can be replaced by simpler ones in a way similar to that described above. The chance for further exercise is both desirable and welcome to such students, and the two variable situation with simple expressions has sufficient novelty to maintain motivation.

The ideas so far discussed are summarized in the following tables.

Insert charts here

Suiting the version to the socially deprived population

So far we have described various versions suitable for different phases in the learning process and referred to two broad types of student, strong and weak. However, there is one large category of student in our population who, on the whole, irrespective or strong or weak, require repeated use of minor variations of the same game.

Over 50% of our student population are officially classified as socially deprived. In fact, it was for this group of students that we first began to publish games seriously, because of the obvious need for motivation. They also constitute a group for whom variations of the same game are important. They enjoy repeating activities in which they feel secure and confident. If suitably motivated, they prefer to repeat the same type of exercise once they have succeeded, rather than attempting new types. Thus variations of one and the same game can help them achieve mastery. An additional point in favour of this for socially deprived students, especially those in the middle of the ability range, is the difficulty of understanding written instructions. By our repeated use of the same instructions we can "neutralize" this difficulty and enable these students to concentrate on developing their mathematical skills.

Especially for such students, but also to some extent in every classroom, the ideal is the game suited by the teacher to the 2-4 players who are to play it. Thus we also provide teachers with sets of 10 "blank" playing boards, on which they can write the sort of expressions at the level at which they wish the students to practice.

Implementation in the classroom

In order to check our first impressions, we selected a sample of classes and using an experimental control group design, tested the effect of the use of the versions of the game in the cognitive and affective domain. In the following we give a qualitative discussion of the results we obtained. In the experimental group we used the following four versions of the game: that given in Fig. 2 as an opener, followed by Fig. 1, then Fig. 1 with a change of rules and, finally, Fig. 3. One lesson period was devoted to each version. Each period consisted of an introduction dealing with general points sufficient for the students to begin playing (e.g. for the first game the explanation of the rules, for the second the omission of the multiplication sign, etc.), the game itself and, at the end more exercises from the textbook or from worksheets. Those of the exercises not finished in class were given as homework.

We asked the teachers to make sure that in each group of 3-4 players there was one good student, at least. During the game, the teachers' role was confined to observation and guidance. They "interfered" only when asked so to do by the students, or if they noticed a student make a mistake.

Student and teacher attitudes

The experimental group consisted of 7 classes (representing different ability levels and socio-economic background). In all of them a positive atmosphere developed, as well as an air of considerable expectancy from one lesson to the next. There was observable evidence of high student involvement. This impression of enjoyment and learning was reinforced in interviews with both teachers and students, as well as in final attitude questionnaires. The following were typical student responses at interview.

"The game helped me a lot in understanding the material, and I really enjoyed playing it. We all tried to solve the difficult exercises and to solve them alone."

"It was fantastic! I didn't need the teacher to help me. I understood the game on my own and also the math through the game. I am sure that I can learn other topics without the teacher if there are more games and I feel I understand better this way."

The teachers' reactions further reinforced this impression. For example the following:

"When I teach this chapter again, I'll definitely use the games."

The 7 classes in the experimental group were matched with 6 similar classes in the control group. The latter learnt the same material using the textbook and conventional teaching strategies. Both from the attitude questionnaire and interview it was clear that the topic was regarded as one of the interesting mathematical topics by those who played, whereas the control students found it relatively uninteresting. However, the reactions were not uniform. There were observable differences depending on the students' level and socio-economic background. Generally, high ability students (but not from the socially deprived population) tired of the game quickly:

"The game was interesting the first time, but after that I was bored. There was no challenge".

Weaker students and students from the socially deprived population (irrespective of ability), on the other hand, the more they played the more they enjoyed it:

"At the beginning I did not want to play but by the end of the lesson it began to be fun. The second game really got me and I wanted to keep on playing after that."

The different needs of students led to various recommendations. Thus for high ability non-socially deprived students it was suggested that the version in Fig. 2 be omitted. Another suggestion to avoid boredom, was to use the game as in Fig. 1 but with the changed rules.

For weak and socially deprived students, on the other hand, it is suggested that they be given the opportunity to play the first version twice (with or without multiplication sign).

In addition to the above, we observed a development of social relations in the classes that played the game. In particular, mutual student help appeared to increase.

The games' influence on achievement

The results obtained with regard to low level skills such as the mastery of substitution in algebraic expressions were as follows. High ability students (including the socially deprived) achieved mastery (over 80% correct responses), whether they played or not. Among the low ability students, on the other hand, those who played scored considerably better on skills than those who did not. In particular, the socially deprived students in the experimental group, not only achieved mastery, but their mean score was effectively identical with high ability students of the non-socially deprived part of the population. As far as the higher cognitive levels, such as understanding and analysis are concerned, there were considerable differences between the experimental group and the control group, irrespective of ability. In particular, the following points stood out:

(a) On the whole, students who played did not regard the expression -x as giving negative outcomes only, whereas control students did.

(b) When asked to chose a number to substitute in a given expression, the experimental students chose positive or negative numbers equally, whereas control students chose positive numbers only. (Although the self-restriction to positive numbers was in greater evidence among the socially deprived, it disappeared in the experimental group to the same extent irrespective of social background.)

(c) Given the number resulting from a (unknown) substitution, experimental students succeeded to a far greater extent in finding the number to be substituted to obtain the given result (i.e. in performing the inverse process, before they had learnt to solve equations).

These latter findings would suggest, that although the Steeplechase was developed primarily to bring students to mastery in a basic skill, the intrinsic encouragement to think out the consequences of moves before they are made, provides us with a considerable bonus. Because the Steeplechase is integrated into the curriculum and demands specific mathematical activity at each move (rather than the general strategical thinking of many so-called mathematical games), the bonus also expresses itself in terms of specific mathematical cognitive achievement relevant to the students' immediate further studies.

Reference

Friedlander, Alex. "The Steeplechase." Mathematics Teaching 80 (September 1977): 37-39. (Also distributed by NCTM.)

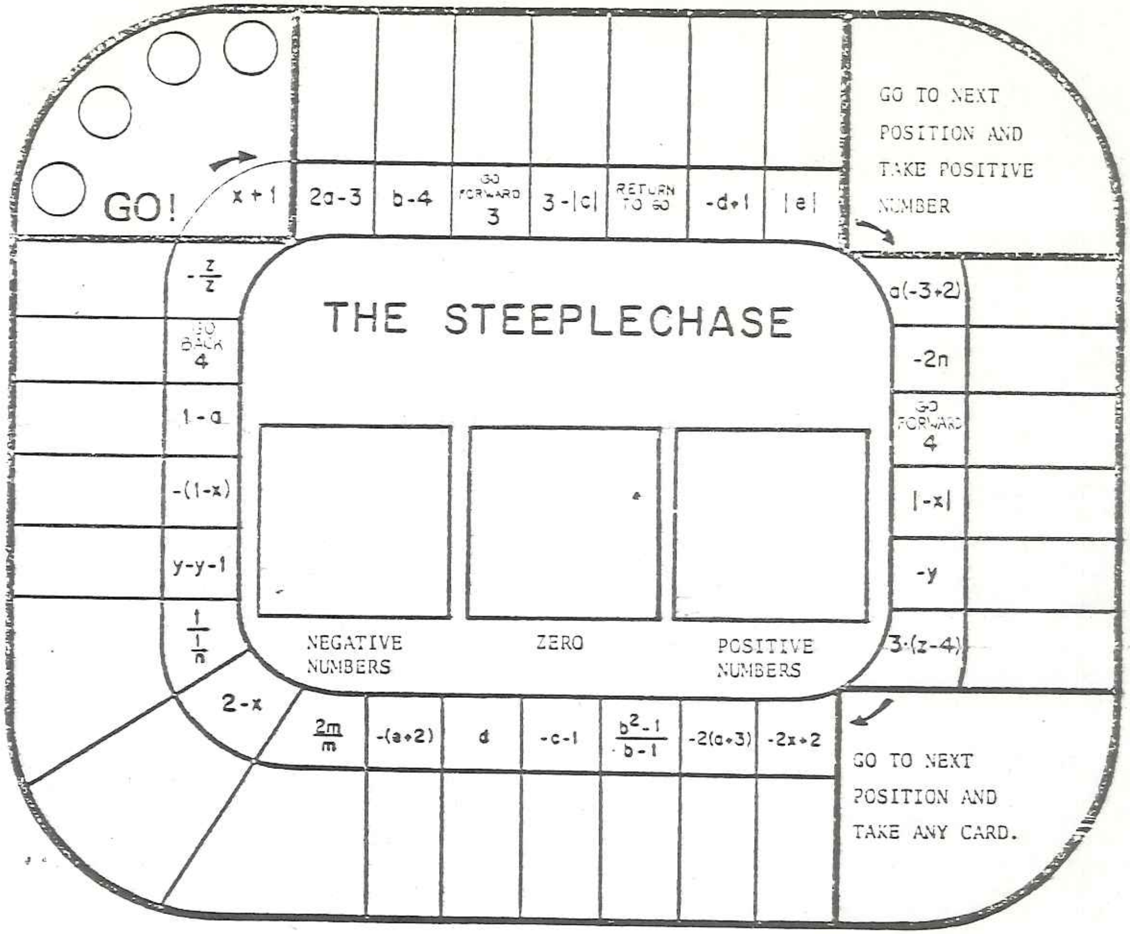
GO!
x + 1
2a-3
b-4
GO FORWARD 3
3-|c|
RETURN TO GO
-d+1
|e|
GO TO NEXT POSITION AND TAKE POSITIVE NUMBER
a(-3+2)
-2n
GO FORWARD 4
|-x|
-y
3·(z-4)
GO TO NEXT POSITION AND TAKE ANY CARD.
-2x+2
-2(a+3)
(b²-1)/(b-1)
-c-1
d
-(a+2)
2m/m
2-x
1/(1/n)
y-y-1
-(1-x)
1-a
GO BACK 4
-z/z
THE STEEPLECHASE
NEGATIVE NUMBERS
ZERO
POSITIVE NUMBERS

FIGURE 1

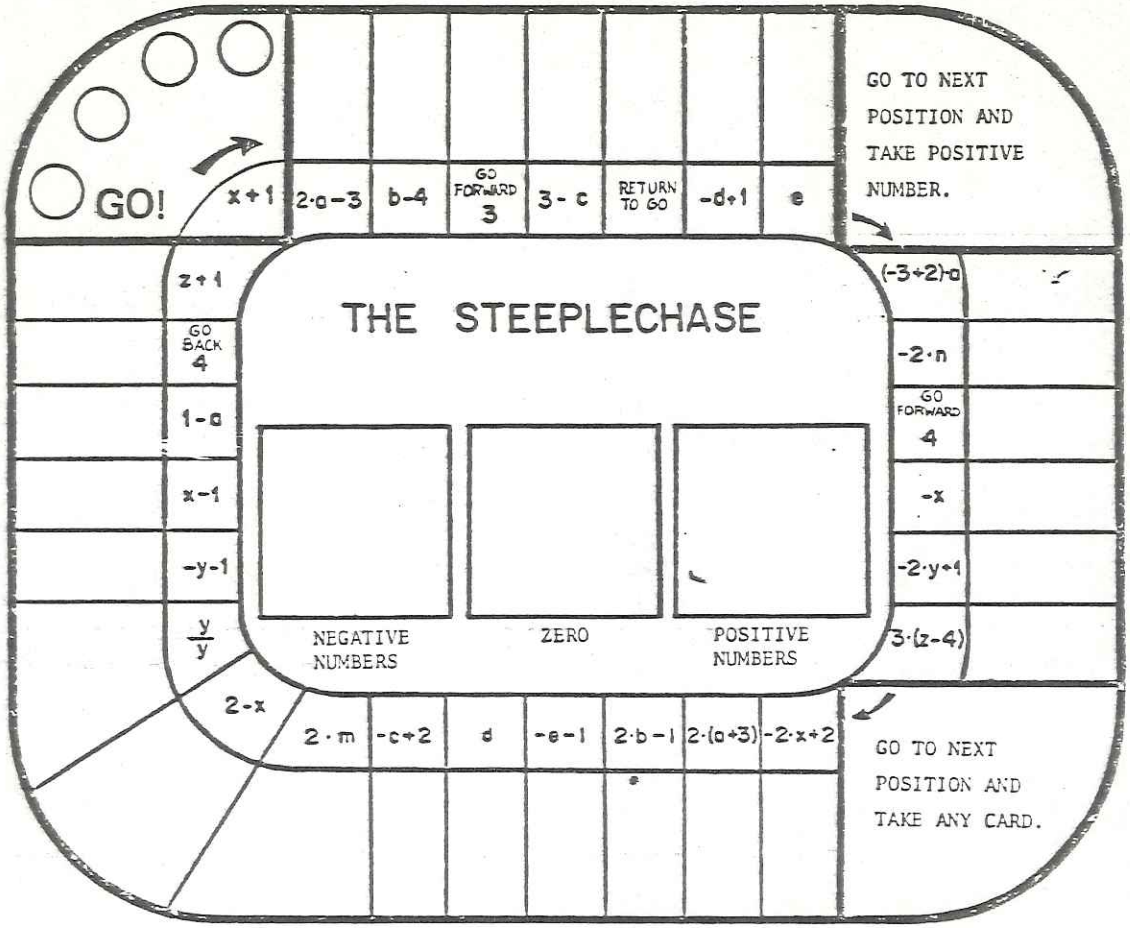
THE STEEPLECHASE
GO!
x+1
2·a−3
b-4
GO FORWARD 3
3 - c
RETURN TO GO
-d+1
e
GO TO NEXT POSITION AND TAKE POSITIVE NUMBER.
(-3+2)·a
-2·n
GO FORWARD 4
-x
-2·y+1
3·(z-4)
GO TO NEXT POSITION AND TAKE ANY CARD.
-2·x+2
2·(a+3)
2·b−1
-e−1
d
-c+2
2 · m
2-x
y/y
-y-1
x-1
1-a
GO BACK 4
z+1
NEGATIVE NUMBERS
ZERO
POSITIVE NUMBERS

FIGURE 2

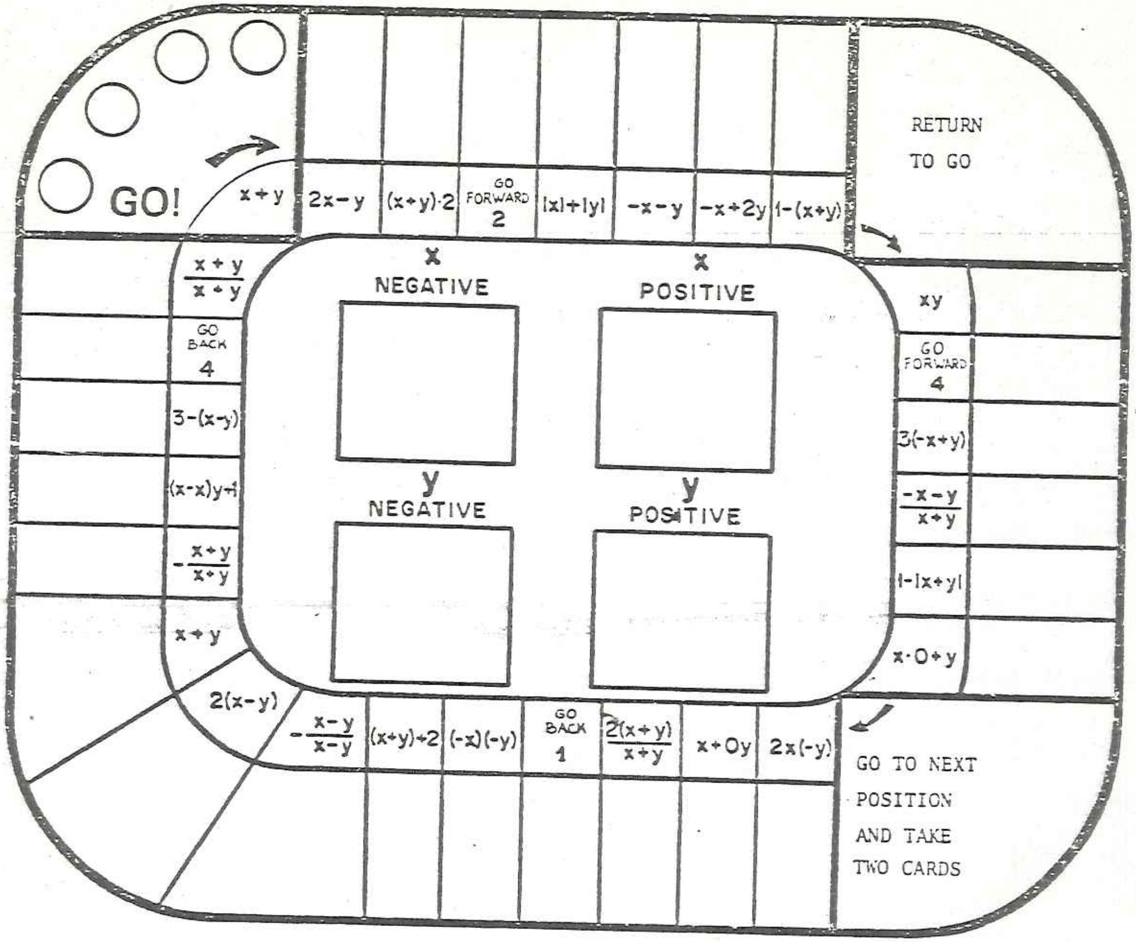
GO!
x + y
2x − y
(x+y)·2
GO FORWARD 2
|x|+|y|
−x − y
−x+2y
1−(x+y)
RETURN TO GO
x
NEGATIVE
x
POSITIVE
y
NEGATIVE
y
POSITIVE
(x + y)/(x + y)
GO BACK 4
3−(x−y)
(x−x)y+1
−(x+y)/(x+y)
x + y
2(x−y)
xy
GO FORWARD 4
3(−x+y)
(−x−y)/(x+y)
1−|x+y|
x·0+y
−(x−y)/(x−y)
(x+y)+2
(−x)(−y)
GO BACK 1
2(x+y)/(x+y)
x+0y
2x(−y)
GO TO NEXT POSITION AND TAKE TWO CARDS

FIGURE 3

Chronological and conceptual charts summarising

the use of the various versions of the Steeplechase

For weak students

Purpose	Versions of the game	Development
Basic ideas in the topic	Fig. 2	Opening lesson
Acquiring skill Development of associated concepts*	Fig. 1	Exercise in substitution
Appreciation of independent roles of "x" and "y"	Simplified form of Fig. 3	Two variable expressions

For strong students

Purpose	Versions of the game	Development
Basic ideas and skills	Fig. 1 with multiplication sign	Opening lesson
Development of associated concepts*	Fig. 1 with changed rules	Exercise in substitution
Development of strategies comprising a number of components	Fig. 3	Two variable expressions

* E.g. the analysis of sets of numbers required to obtain a given result.