STUDENTS' STRATEGIES AND REASONING PROCESSES IN COMPUTER EDUCATIONAL GAMES

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Children usually enjoy all kinds of games and tend to view microcomputers as friendly gaming machines (Greenfield, 1984). Traditionally, games were not regarded as suitable educational activities. However, a gradual change in this respect occurred in the last decades, mainly as a consequence of the emergence of new societal values.

A number of quite interesting and challenging educational games have been developed. It is necessary to assess the educational value of these programs and to consider their cognitive, affective, and social implications (Ponte, 1986).

The most important feature in a game is the existence of a defined goal, which is opposed in a systematic or random way by one or more adversaries, according to some well-defined set of rules. To be considered educational, a game must be able to make a specific or general contribution to the process of children's growth, either in terms of learning, motivation, or development of self-confidence.

This study is concerned with the use of concepts by children and their thinking strategies playing educational games. It uses four computer games, all dealing with number concepts (factor, prime, negative number, order relation, and approximation) but requiring distinct strategies. These games were either developed or adapted at the Departamento de Educação da Faculdade de Ciências da Universidade de Lisboa.

Pilot work was conducted with 12 elementary and middle school children yielding minor modifications in the games and suggesting strategies of data collection. In the formal study, subjects were 16 fifth- and sixth-graders at a school in a suburban area, not far away from Lisbon. Most of the students had worked with computers before, either at home or in school extra-curricular activities.

Every game was played for about 30 minutes. The students worked in pairs or in groups of three, allowing the researchers to follow their discussion as they went through each game. In one game, data was also collected by the computer, recording students' critical moves.

The games were played in the order in which the main observations and results are reported below. The researchers introduced each game with a brief demonstration, explaining its rules, but keeping themselves of giving any clues concerning possible winning strategies, except in a few cases that will be specifically commented.

Observations and Results

WHERE IS TRAQUINAS HIDDEN? This game is a modification of the well-known HURKLE. The character, Traquinas, jumps around a few places and finally hidden in a number line marked from -10 to +10. The student is asked to guess the place where Traquinas is hidden and following each erroneous guess a clue is given (larger number, smaller number). Wrong guesses yield scores that increase quadratically with the number of attempts.

Since students had not been taught about negative numbers before and some of them were not completely familiar with the computer keyboard, there was a brief informal introduction on how to get these numbers on the computer.

Observations:

1. All students understood the gaming situation: Traquinas is hidden in one and just one place. They readily accepted that negative numbers were some sort of an "extension" of the natural numbers. Some of them said to know these numbers, mostly in connection with temperatures. Others did not immediately understood that each mark in the number line corresponded to one number. However, this kind of difficulty seemed to be easily overcome. Scores did not attract the attention of the students.

2. There were marked differences in the facility with which students grasped how to extend the relationship "greater than" to the new number context. Some of them thought that the number immediately left to 0 was -9. After a few trials some students appeared to have understood pretty well this relationship, while even in the end of the game others seemed still quite confused.

Some students interpreted the clue, "it is in a larger number," as "it is in a positive number," and the clue "it is in a smaller number" as "it is in a negative number." This is a good example of a tendency to think about relative entities in absolute terms. In these
cases they were helped to clarify the notion of larger and smaller, to be able to properly interpret the clues given by the computer. In most instances these explanations were understood, at least as could be observed in subsequent trials of the game.

(3) A number of strategies were identified:
(a) "Jump around." If the computer says that the number is larger, jump to a much larger number. In most cases only the information conveyed by the last trial was taken into account, leading some students to guess for more than once in the same number.
(b) "Go up or down just one number." This is a "safety strategy," which in general yields high scores.
(c) "Systematic division." Start with zero. Then proceed dividing in two equal parts the intervals were Traquinus is said to be.
(d) Search for a "smart strategy." He may be hidden in the last place he showed up... or, perhaps, in the place where he glanced for the first time...

The game was useful in providing a context for the introduction of the number line representation of integer numbers. Even when the concepts were not immediately grasped, a brief discussion seemed to provide enough basis for understanding.

MULTIPLICATION CONTEST. This game is a competition among two to four players, requiring the execution of single or multidigit multiplications. In each question each player is allowed at most three guesses. The score is a function of the number of guesses and the time required to give the correct answer. The player that first reaches a predetermined score wins the game.

Students were suggested to play in a way such that all multiplication questions involved numbers below 15. This game induced an easy involvement of all the children and its general features and purpose were immediately understood.

Observations:
(1) Some students consistently failed in some multiplication facts (6x7, 9x7, 6x9, ...). Several students never used fast strategies of multiplication by 10. Again, some students did not pay much attention to the time counting features of the game.
(2) At least in some trials all students used some mental representation of the multiplication algorithm. Some students accompanied this representation with the figuration of the algorithm using their fingers. To several students this mental representation was not effective as they failed consistently to multiply by the second figure ("twelve times three,... six, carry one,... sixteen": "twelve times nine... two times nine is eighteen, carry one,... twenty eight").
(3) Some students used the commutative property to remember some multiplication facts ("five times six... six times five is thirty"). Only two students were noted using distributivity to remember a multiplication fact ("seven times five... six times five is thirty... thirty five").

With an encouraging presence of the teacher, this game appeared to provide an enjoyable setting to recall some basic arithmetic and to practice mental computation.

BIG ESTIMATION CONTEST. In this game each player is asked an estimation of a multidigit multiplication. As the previous game, it is a competition among two to four players, with three guesses to each question. The score is a function of the number of guesses, the accuracy of the response, and the time required to give an acceptable estimation.

The game was introduced with a brief demonstration in which students were explained the concept of approximation.

Observations:
(1) Some students refused completely the concept of approximation, and played the game as if it required precise responses. Others, although seemingly understanding the general idea, had no tolerance for errors and preferred to give exact answers ("more or less is not good"), spending a lot of time in each question.
(2) Several strategies were noted:
(a) Rounding. Just round one of the numbers to the nearest tenth. Example: 19x13 --> 20x10.
(b) Double rounding. Round both numbers to their nearest tenths. Example: 19x12 --> 20x10.
(c) Rounding with compensation. Use one of the above strategies and add or subtract a compensating quantity. Ex. 97x72 --> 100x72 - something.
(3) Rounding and double rounding strategies were explained in the beginning and were most commonly used.
(4) For some students the idea of rounding was difficult to grasp and they preferred to truncate the numbers. Example: 17x12 --> 10x12.
(5) Most students had no idea of the size of the numbers they were going to obtain. For example, the double rounding strategy led one student to reason that: 4x39 --> 1x40, and 2x17 --> 17.

This game was acceptably understood by part of the students and...
poorly by others. It required a big conceptual leap from students’ previous experience. To be useful in the classroom the game needs a lot of teacher involvement and support and the articulation with other estimation oriented activities.

TRINCA-ESPINAS. This game is a Portuguese adaptation of the popular TAXMAN. From a given list of numbers we pick up numbers and the computer picks its divisors. Only numbers with divisors on the list may be picked by us and in the end the numbers left are taken by the computer.

The game was introduced with a demonstration trial, using a list of 12 numbers. The first number picked was 10, and that was used to explain the rules. Students were then encouraged to play by themselves in a few trials with lists of 12 numbers. If they did not succeed in winning the computer, they were further suggested to come down to lists of 7 or even of 5 numbers. From a winning point, students were then encouraged to play with larger lists of numbers.

Observations:
(1) Almost all students succeeded in understanding the game. The fifth year students who had not been formally introduced to the mathematical notions of divisor and multiple, involved in the game, showed easiness in using these concepts.

(2) Strategies:
(a) What is the first number to take? After several trials most students realized that it was the largest prime.
(b) What are the next numbers to take? Some students tried numbers with just one factor, beginning in the smaller numbers on the list. This is a sort of a “safety strategy” leading to poor results. Some others seemed to follow a similar strategy, but beginning in the higher numbers on the list. This strategy was not always strictly applied, probably because some of the possible candidates were overlooked, but generally conducted to good results.

(3) The largest number may conduct to two almost opposite situations. Either the desire of taking it immediately, regardless of its divisors, and some students took first 12 in the 12 number list, or the desire of not taking it at all, and some students disregarded it in the 7 number list. Also, numbers with many divisors (like 12, 8, and 6) are a temptation for an early collection, almost always with very poor results.

This was the most enjoyed game, despite the fact that no student was able to get better than a win with a list of 25 numbers. Fun seems to be higher when children perceive a real challenge from the computer but feel able to overcome it.

Conclusions

Overall the students enjoyed the two-hour session in which they played these four games. They were becoming somehow tired with the sequence multiplication-estimation, but wellcome the last game, TRINCA. To end the sessions it was necessary to declare them over, since students would not leave just by themselves.

The requirement of mathematical concepts not previously studied was not a barrier to students’ involvement in the games. They provided a stimulating environment for the introduction of these concepts, on which formal teaching could build. This supports Bright et al. (1985) contention that games can be used in pre-instructional settings. The first contact of young children with computers induces usually lots of excitement (Malone, 1992). This early enthusiasm does not stand for a long time, but can be used to foster an initial positive contact with modern technology.

Besides providing a stimulating learning environment (Kraus, 1984), educational games also allow teachers to obtain a more global view of their students’ processes and difficulties. However, one should be reminded that the use of computer educational games should always be well planned. To be of real educational value, games should be components of a more general set of activities to be performed in articulation with them.

References


