Inquiry Approach in Learning Selected Computer Science Concepts

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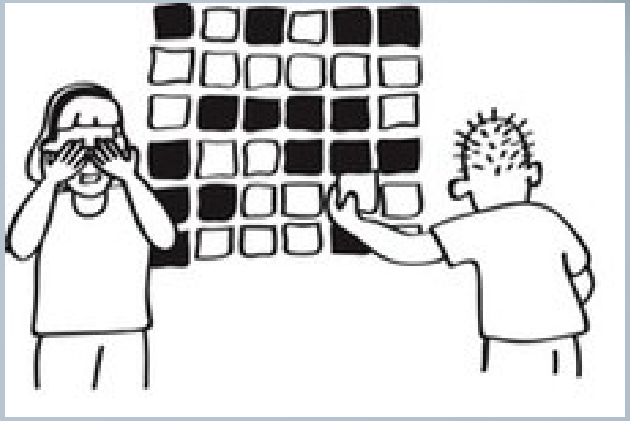
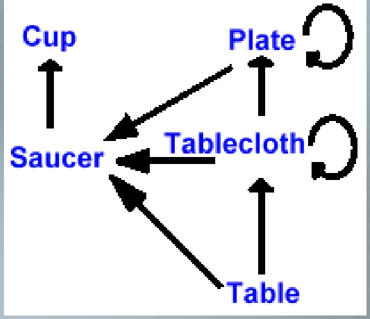
Introduction

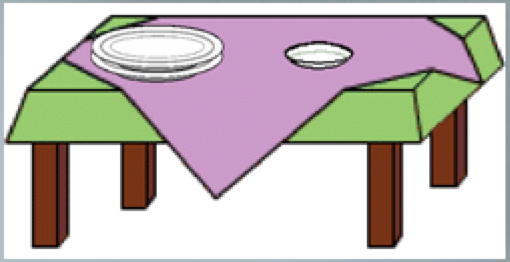
- Difficulties in understanding CS concepts - transmissive way of teaching.
- Many CS teachers know about modern approaches (PBL, IBL, DL, etc.) and their benefits (increasing of pupils' engagement and activity, involvement of higher-order thinking, developing their curiosity, critical thinking, etc) but don't exploit them in their everyday teaching
  ("there is no time to let pupils think more deeply", "our pupils are not so clever", etc)

Inquiry approach – examples

- Basic CS concepts, principles and rules can be of observed, discovered, etc. by pupils on various school levels in various depth by solving authentic/interesting problem, experiental activities – games, tricks, role playing, etc. (CS unplugged, CS4Fun, iBeaver)



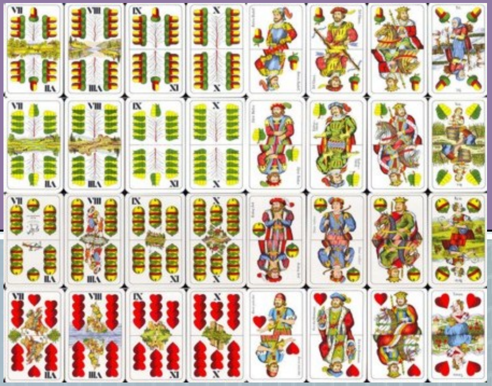




Card Guessing Game – methodology

- Exploiting the Learning cycle a 5E model (BSCS, 2006):
  - demonstrating magic, asking questions (engagement);
  - playing the game in pairs, finding out best way of card guessing with no or little help of a teacher (exploration);
  - discussion results, comparing findings, giving explanation for pupils' findings in scientific language (explanation);
  - solving a related or more general problem (extension);
  - asking high-order questions, assessment (evaluation).

Card Guessing Game – teacher's information



- Main problem:
  - Find and describe as well as possible the way how to guess one card chosen from a package of German cards.
- Further problems:
  - Find and explain as effective way of calculating the amount of information necessary for finding the chosen card as possible.
  - Find and explain the relationship between the length of encoding (number of digits), logarithm and depth of N-ary tree.

Card Guessing Game – teacher's information

- Topics:
  - Information encoding.
  - Calculation of information quantity.
  - Binary searching of elements in an ordered sequence.
- Learning aims:
  - Discovering and application of binary search algorithm to guessing cards/numbers.
  - Explaining that the amount of information necessary to determine a chosen card depends on the total number of cards and also on the manner of questioning (the number of different answers to the questions).

Card Guessing Game – teacher's information

- Learning aims (2):
  - Explaining that after each answer to a question more and more information is acquired, after binary question 1 bit of information is acquired, (after ternary and decimal questions 1 trit and 1 dit of information are acquired respectively).
  - Giving reasons that for clear determination of one chosen card from a package of 32 cards we need to ask 5 binary questions (for one from 27 cards we need to ask 3 ternary questions, in general for determination a card from a package of N cards we need to ask $\lceil \log_K N \rceil$ K-ary questions at most).

Card Guessing Game – teacher's information

- Prior knowledge:
  - Calculating with various positional numeral systems (writing successor of a number, conversion of number notation between various bases).
  - Using logarithmic and exponential functions.
- Target groups: upper secondary school pupils, university students – pre-service teachers)
- Used materials: a pack of 32 German cards, dataprojector, (interactive) board.
- Time requirement: 1 lesson

Card Guessing Game – process

- 1st phase – teacher demonstrates the card guessing game and encourages pupils to play the game in pairs, they take turns to guess cards.
- 2nd phase – pupils (independently of a teacher or by the little help of teacher) discover a sophisticated way of determining the chosen card.

Card Guessing Game – process

- 3rd phase – after playing the card guessing game, pupils will study information encoding by means of binary numbers, calculate the amount of information and use binary tree for searching, information encoding and showing unambiguity of encoding.
- 4th phase – pupils are encouraged to solve further problems leading to generalization and exploiting various ways of encoding information in solving some practical problems. Finally, the teacher assesses pupils' understanding of the concepts

Example of dialogue – 1/7

- Teacher: “Considering the random guessing of a card, can we guess the card on the first try?”
- Pupil: “Yes, but in this way we will not be always successful.”
- Teacher: “How many trials we can reach in the worst case?”
- Pupil: “Well, when we have a great misfortune, till the 32nd attempt.”
- Pupil2: “We can do maybe more than 32 attempts, but I think that 31 attempts will be sufficient for guessing in the worst case.”

Example of dialogue – 2/7

- Teacher: “What can we say about a set of cards with searched card during gradual questioning?”
- Pupil: “That this set will reduce question by question.”
- Teacher: “How will it reduce?”
- Pupil: “After each question this set will be one card smaller.”
- Teacher: “Yes, in a random guessing a set with searched card will shrink by 1 until we guess the searched card.”

Example of dialogue – 3/7

Next, the teacher puts the cards on the table face up and organizes them by colour (suit) and values. He/she can use also data projection for showing the cards to all pupils and continues a dialogue.

- Teacher: "Try to ask a question in order to reduce the set with the searched card by more than only one card?"
- Pupil: "Is it green?"
- Teacher: "Yes, great. How big will be a set with searched card?"
- Pupil: "If the answer is "yes" then searched card will be one of 8, otherwise one of 24 cards."

Example of dialogue – 4/7

- Teacher: “OK. Try asking question in a way so regardless of the answer “yes/no” to have equal chances in which group the searched card would be.”
- Pupil: “Is the value of the searched card a number?”
- Teacher: “Excellent. And how will it reduce a set with the searched card?”
- Pupil: “By half.”
- Teacher: “Yes, exactly. Now try to ask a question concerning colour of the searched, which narrow the set with the searched card in half.”
- Pupil: “Is it red card or green?”

Example of dialogue – 5/7

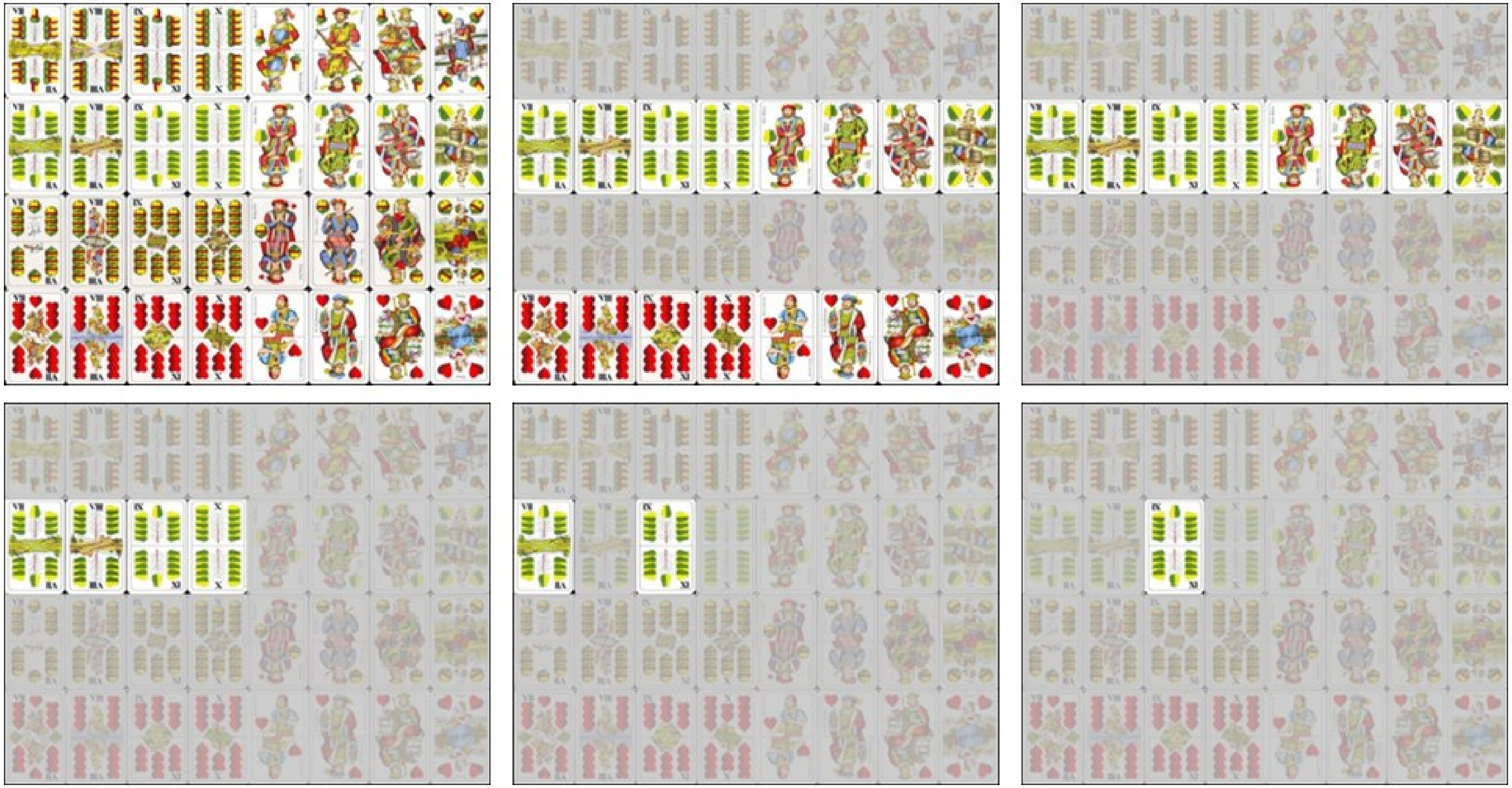
- Teacher: “Excellent. Is the colour of the searched card some from the following colours: red, green? What will be the further question concerning colour of searched card?”
- Pupil: “Well, after this question I know that searched card is either from colours set {red, green}, or colour set {acorn, ball}. Then I ask for one colour from the selected set. E.g. when the first set is chosen, so I ask – Is it red? And then I definitely know what colour has searched card.”
- Teacher: “Yes, first you asked about one pair of colours and then you asked about one of them. At the beginning we have 32 cards. After answer of the first “yes/no” question a set with the searched card reduced to 16 elements, after next answer to 8 elements.

Example of dialogue – 6/7

- Teacher: ”I believe that it wouldn’t be difficult for you to propose further questions for determining the value of the searched card.”
- Pupil: “I ask whether the card is a number. After answering this question only 4 cards_remain. Either they will be numbers, or figures. After my next question only 2 cards will remain and finally by the last question I will definitely assign the searched card.”
- Teacher: “Perfect. During asking questions there is important to find and to formulate a convenient attribute through which a set with the searched card will be reduced. How many questions did we need for guessing, or finding the searched card?” – Pupil: “5.”

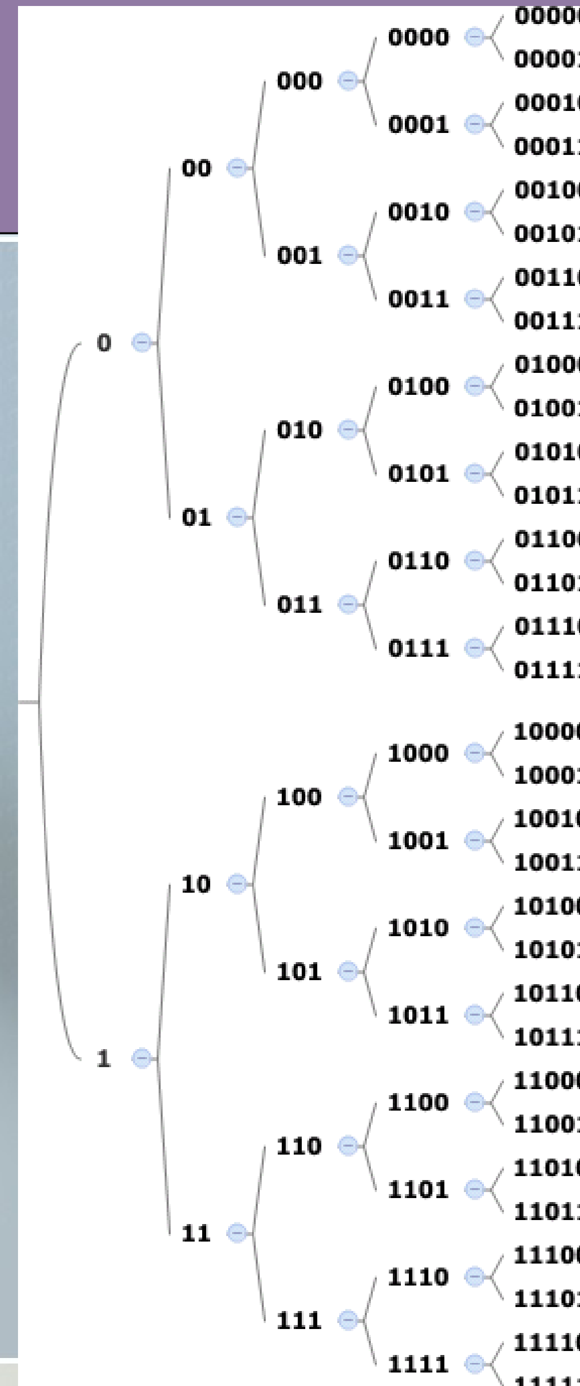
Example of dialogue – 7/7

- Teacher: "Yes, we need 5 questions. At the beginning a set with the searched card has 32 elements. After each answer this set will reduce by half gradually to 16, 8, 4, 2 cards and finally to 1 card, which is illustrated in the Figure.



A binary tree

- a useful tool for:
  - understanding the relationship between the total number of elements (e.g. cards) and the number of bits necessary for encoding all the elements and also the number of binary questions for finding out a search element;
  - unambiguity of encoding.



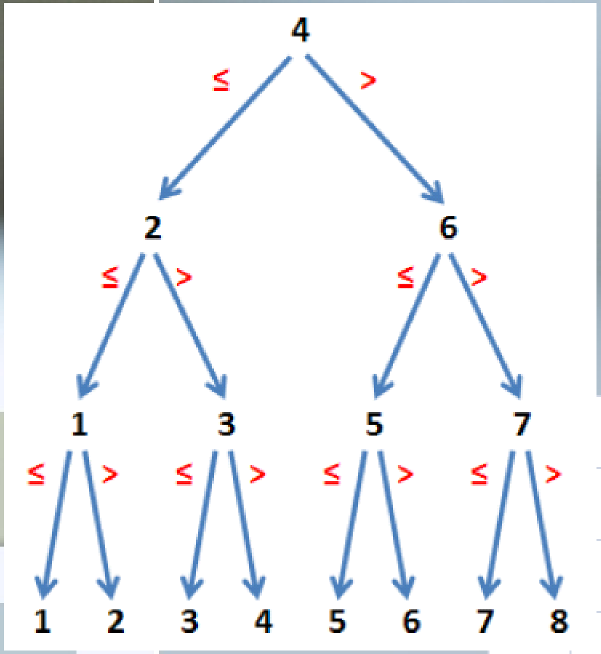
More examples, more generalisation

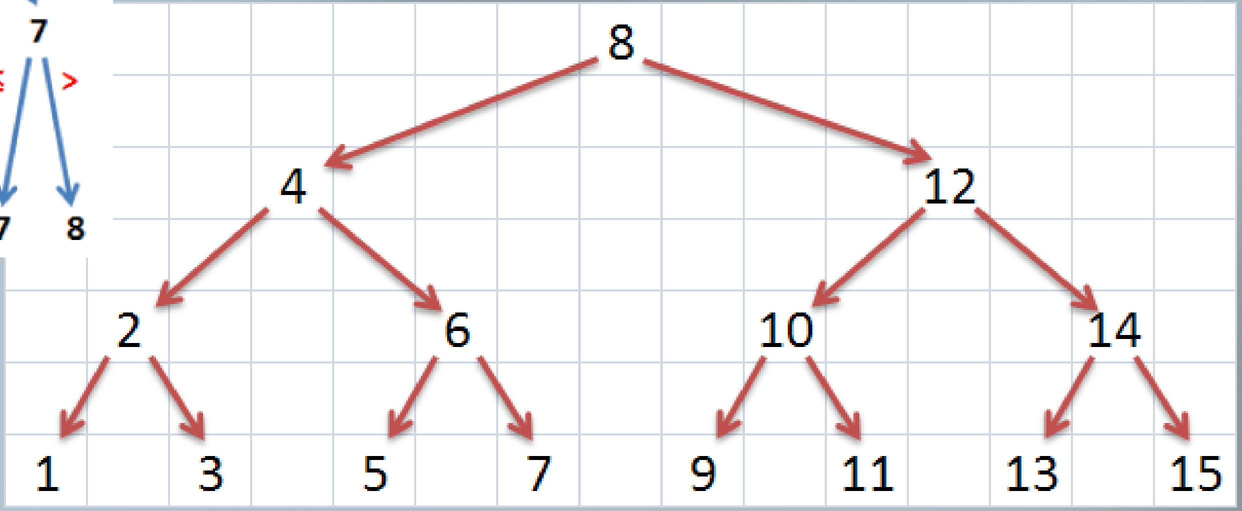
- Determining of a player's order in special play off torunament (each of 2^K players plays equal K number of games)

win win win win win	00000
win win win win lose	00001
win win win lose win	00010
…	
lose lose lose lose lose	11111

More examples, more generalisation

- Guess number game





More examples, more generalisation

- Magic with guessing number

decimal	binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

4th card 1xxx	3rd card x1xx	2nd card xx1x	1st card xxx1
0000	0000	0000	0000
0001	0001	0001	0001
0010	0010	0010	0010
0011	0011	0011	0011
0100	0100	0100	0100
0101	0101	0101	0101
0110	0110	0110	0110
0111	0111	0111	0111
1000	1000	1000	1000
1001	1001	1001	1001
1010	1010	1010	1010
1011	1011	1011	1011
1100	1100	1100	1100
1101	1101	1101	1101
1110	1110	1110	1110
1111	1111	1111	1111

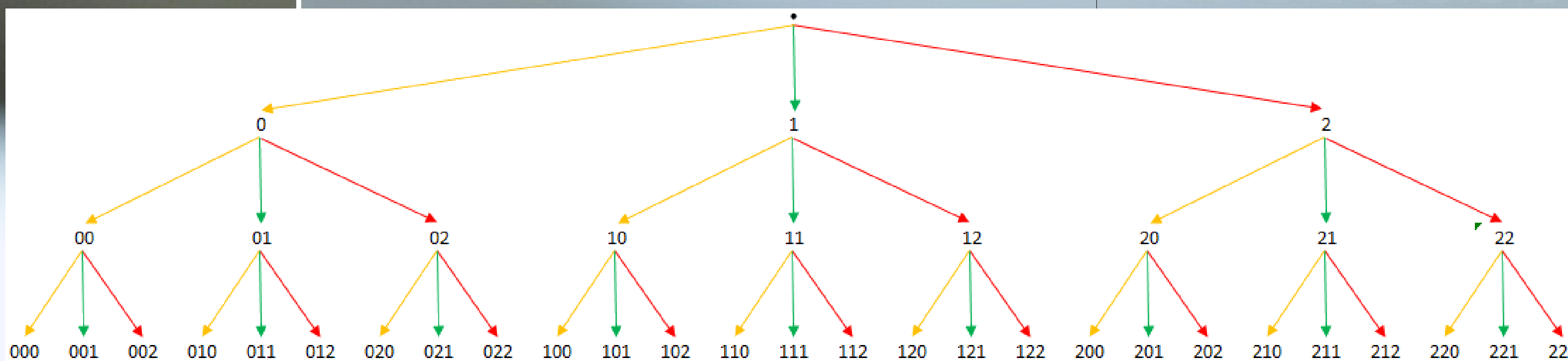
4th card 1xxx	3rd card x1xx	2nd card xx1x	1st card xxx1
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15

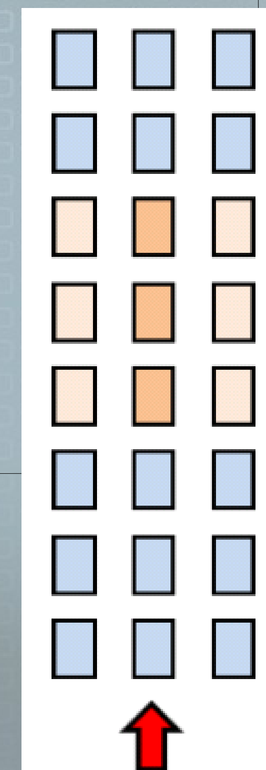
4th card	3rd card	2nd card	1st card
1000	0100	0010	0001
1001	0101	0011	0011
1010	0110	0110	0101
1011	0111	0111	0111
1100	1100	1010	1001
1101	1101	1011	1011
1110	1110	1110	1101
1111	1111	1111	1111

4th card	3rd card	2nd card	1st card
8	4	2	1
9	5	3	3
10	6	6	5
11	7	7	7
12	12	10	9
13	13	11	11
14	14	14	13
15	15	15	15

More examples, more generalisation

- Guess a card layed into three rows





- For determination a card from a package of N cards we need to ask $\lceil \log_K N \rceil$ K-ary questions at most.

Discussion

- Proposed inquiry activities with methodology comments are based on teaching experience with
  - **various target groups** (elementary school pupils, gifted pupils from secondary schools, pre-service and in-service computer science teachers)
  - **various problems** (looking up a word in a dictionary, guessing integer number from 1 to 16 (or from 1 to 26) using binary spiders (or special treated cards), guessing one of 32 (or 27) cards obtaining binary (or ternary) answers, encoding two coloured pictures by binary numbers etc.)

Discussion

- In different target groups it have achieved different width and depths of subject matter comprehension.
- Pupils from 3rd class of elementary school have discovered a better way of looking up a word in a dictionary than browsing the dictionary page by page. They understand that “spider” (binary tree) is a very good aid for guessing integer numbers in a few trials.

Discussion

- Gifted high secondary school pupils very quickly discovered a principle of effective guessing a card using binary (or ternary) questions. They were very active, asked many questions, created and verified hypotheses, were very consistent and critical etc.
- Pre-service and in-service computer science teachers appreciated the magic with cards as a very appropriate activating teaching method.

Discussion

- Teachers can devise special packs of cards instead of German cards (e.g. cards with computer devices, binary numbers, animals, fruit), which could be more appropriate for younger pupils and would help to remember selected notions of computer science, too, or which would have a closer relation to other school subjects.
- For inquiry approach it is also very helpful to use computer animations, demonstration videos and interactive applets.

Conclusion

- Playing games is fun and revealing magic is big challenge for pupils, so why not to use it in our teaching?
- It helps not only to acquire scientific knowledge, but also develop pupils' inquiry skills, exploiting science to real life and strengthening of positive attitudes to science
- We believe that proposed inquiry activities with methodology comments will be inspirational and worth for computer science and math teachers

Conclusion

- We will improve existing an prepare new one inquiry activities and deliver them to in-service and pre-service teachers via publishing on web, journals, presenting at seminars, conferences, workshops etc.

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  - ESTABLISH
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    Developing youth talents via correspondence seminars and competitions

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