How students think and solve algorithmic problems - findings from programming competition

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Curriculum of informatics

- **Decision latitude** - teachers can select areas, scope and tools
- **Differences** in final knowledge and skills of pupils
- How can we know more about content and scope of education in area of **algorithm development and programming**?
  - **Qualitative research method** - content analysis of non-verbal data obtained in competition PALMA junior
  - **Methodical preparation** of competition assignments, regarding phenomena we are going to research into

PALMA junior

- **Online programming competition** was established in 2005, organized by P. J. Šafárik University in Košice, Faculty of Science in Slovakia, for pupils aged 10 to 16
- Programming environment is **Imagine** based on programming language LOGO
- Problems are oriented to **programming**, **algorithm development**, **mathematics**, aesthetical feeling etc.
- The assignments of the problems use story style in order to lead the pupils **to identify the problem** hidden in short story
- Understanding of assignment (**reading literacy**) is very important pupils' competence, needful for successful problem solving

What we are interested in

- **how pupils think** and combine present knowledge, processes and methods they use,
- **typical misconceptions** of pupils' solutions of problems and error analysis (errors, oversights and inaccuracies).
- We utilize our findings while preparing new problems for the next bout of competition. We have verified or reformulated our up-to-date theory (account of phenomenon couched in notions and interrelations among them).

Precision and efficiency of solutions

- Pupils often ignore differences between their solutions and given specification and conditions. Precision and sense of details have not reached required level yet.
  - Do they underestimate problem analysis?
  - Aren’t they able to create mathematical model?
- Question of efficiency is not fundamental for pupils, they are satisfied with function routine regardless of its efficiency.
  - Do they have needful knowledge and skills?
  - Are pupils able to determine the efficiency of their procedures?
  - How can we bring idea of efficiency home to pupils?

Generality of solutions and level of parameterization

- Pupils make use of generality in many activities, whether at school or in daily life. But problem is to create own general algorithm.
- Pupils aware need of generality, but they haven't attained a required level of abstraction (they solve the problem for specific set of input, even only for one used as illustration in assignment of problem).
- Pupils prefer specific values (not parameters), number of procedures with similar codes instead of one procedure with several parameters.

Compound statements

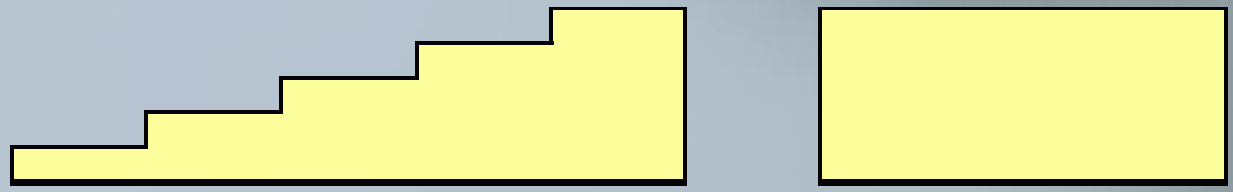
- Conditions
  - Pupils' solutions indicate **deficient analysis of problem and insufficient knowledge and skills** – whether mathematical or programming ones.
- Loops
  - Pupils do not get view of benefits for using loops to solve the problem in other ways.
- **Problems with visual outputs** help pupils to verify the validity of typed conditions and loops, and correct them.

Our scope

- Via **individual commentaries to pupils' solutions** we would like to call their attention to shortcomings of their solutions.
- **Authors' solutions** are useful not only for pupils, but also for teachers who use competition problems and their authorial solutions also in regular informatics lessons.
- **Well-formed system of consequential problems** can convince pupils of benefits from knowledge in efficiency, generality, parameterization, compound assignments etc.

Preparatory phase of the competition

- In preparatory phase of the competition is reasonable solving old and easier preparatory problems.
- It is similar to move up a stairway. If we want to reach the higher level we need to manage certain number of steps with adequate height.



A graded sequence of preparatory problems

- Analysis of pupils' solutions of competition problems brought us pupils' misconceptions and errors and various levels of algorithmic thinking
- How to create a graded sequence of preparatory problems:
  - analyzing author solution of a problem and specifying used elements of subject matter
  - creating set of several easier problems which cover analyzed elements and reorder them (pupils' errors)
  - creating system of consequential problems as oriented graph
  - designing graded sequence of preparatory problems

System of consequential problems – example

- Original competition problem:
  - *National flags of six founder members of European Union consist of three colored stripes. Create procedure (s) for drawing these flags.*
- Designing 4 levels of problems:
  - 1st level – elementary, trivial
  - 2nd level – preparatory
  - 3rd level – competition
  - 4th level – advanced

Level 1

- procedures without parameters
  – drawing square and rectangle
- Problems:
  - Draw square with given size e.g. 100 points (procedure **square**)
  - Draw rectangle with given sizes e.g. 100×200 points (procedure **rectangle1**)
  - Draw one-color filled rectangle with given sizes e.g. yellow with 100×200 points (procedure **rectangle2**)

Level 2

- procedures with parameters
  – drawing rectangle
- Problems:
  - Draw rectangle with two sizes assigned as parameters (procedure **rectangle3 :a :b**)
  - Draw one-colored rectangle with two sizes and one color assigned as parameters (procedure **rectangle :a :b :color**)

Level 3

- procedures with parameters
  – drawing three stripe flag
- Problems:
  - Draw three-colored rectangle with two sizes and three colors assigned as parameters
    (procedure **flag1 :a :b :color1 :color2 :color3**)
    (procedure **flag2 :a :b :colors**)
  - Draw three-colored rectangle with two sizes and three colors and stripes orientation assign as parameters
    (procedure **flag3 :a :b :colors :orientation**)

Solution of competition problem

```
to flag3 :a :b :colors :orientation
  ifElse :orientation=90 [let "x :a
                          let "y :b/3
                          forward :x
                          right 90]
                         [let "x :b
                          let "y :a/3]
  repeat 3 [
    rectangle :y :x item repcount :colors
    forward :y]
  back 3*:y
  if :orientation=90 [left 90
                      back :x]
end
```

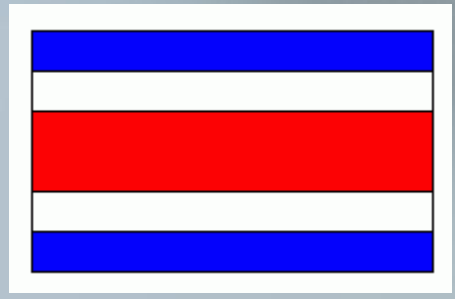
Level 4

- drawing flags with further parameterizations
- strength of procedures
- using it in other contexts
- using various information sources
- Questions:
  - What kind of pictures is the procedure flag3 suitable for?
  - Find all nations whose flags can be drawn by the procedure flag3.
  - Do you find a state with three colored stripes flag which can not be drawn by procedure flag3?

Level 4

- Problems:
  - Draw three stripe flag with various widths of stripes (procedure **flag4 :a :b :colors :orientation :ratio**)
  - Draw flag with more stripes with equal width of stripes (procedure **flag5 :a :b :colors :orientation**)
  - Draw flag with more stripes and with their various widths (procedure **flag6 :a :b :colors :orientation :ratio**)

Flag of Costa Rica:



flag6 120 200 ["blue "white "red "white "blue] 0 [1 1 2 1 1]

Level 4

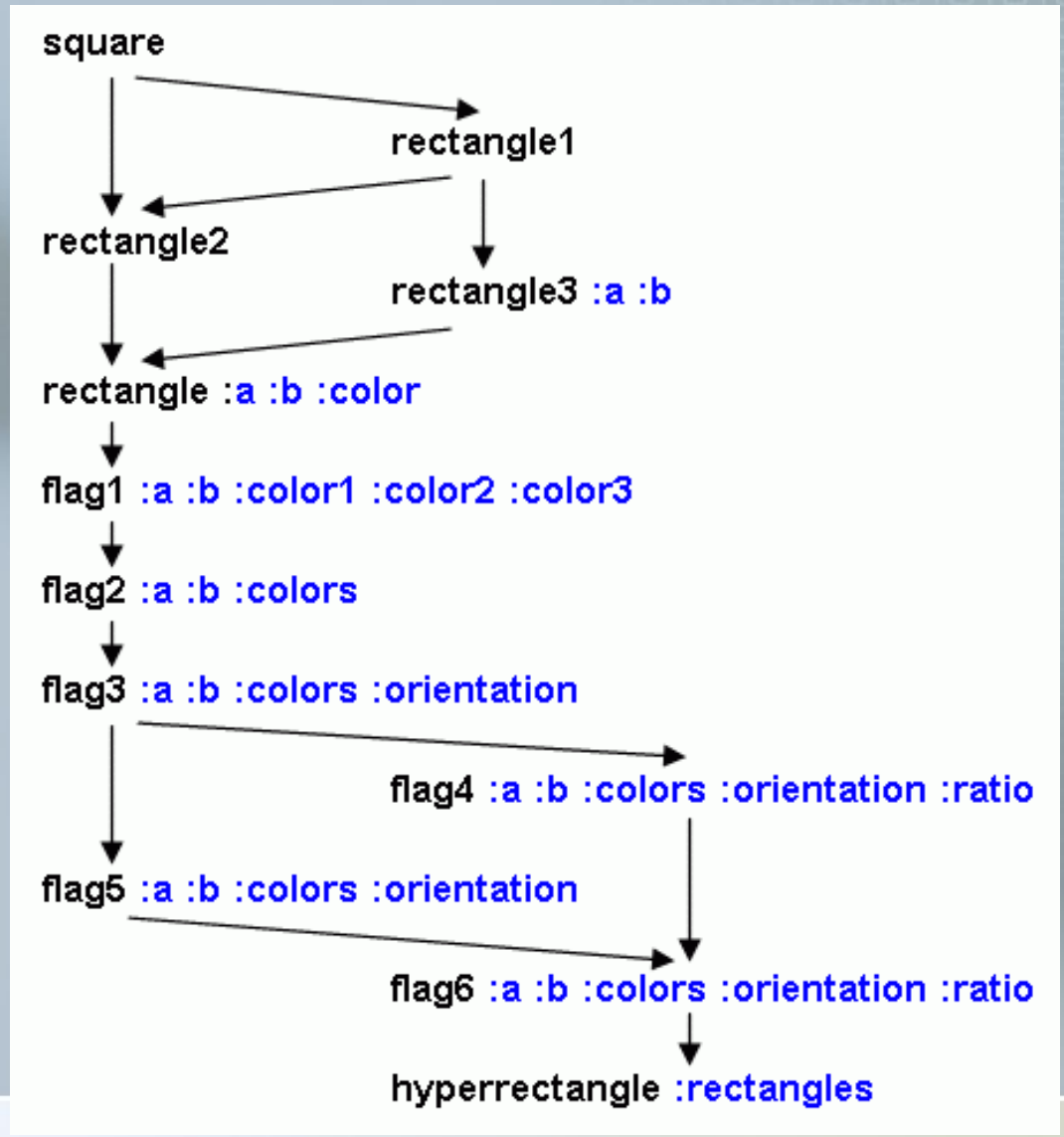
- further parameterization

- Flag of Benin:

```
flag7  [[100 50 “green [0 0]]
       [50 100 “yellow [50 50]]
       [50 100 “red [50 0]]]

flag8 [[[r 2 “green] [c 2 “yellow]]
        [[c 2 “red]]]
```

System of consequential problems – scheme



Conclusion

- The PALMA junior competition is beneficial for 3 groups – pupils, teachers, **preparatory and working team**:
  - publishing study material, assignments, authorial solutions and typical pupils' errors on the competition web site.
  - a resource for our research in the field of problem solving and programming education.
    - systematic approach: choosing problems covering all four competition aims,
    - analyzing pupils' solutions, their way of thinking, misunderstandings and errors,

Future plans

- In the frame of a new project
  - to continue in our research oriented to development of algorithmic thinking
  - to create and publish collection of solved problems with methodological commentaries
  - to prepare and realize distance course on methodology of programming
  - to help informatics teachers to improve their teaching and also to improve programming skills of young programmers indirectly

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Thank you for your attention

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