Teaching Programming in Secondary School: A Pedagogical Content Knowledge Perspective

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Seminaire IDEES

26 mars 2012

Foreword

About this article

- Published in *Informatics and Education*, 2010. Freely available online.
  `http://www.mii.lt/informatics_in_education/htm/INFE177.htm`
- Authors' institution: *Eindhoven School of Education* (centered on science)
  Three main goal:
  - Teach science to future teachers
  - Conduct research on these themes
  - Support and promote innovations in teaching

About this presentation

- Based on the article, or at least, on my understanding of the article
- You should read the original article for safety
- Please interrupt me if you have questions
- Remember: this is not my own work (it's not even my usual topic ;)

Back to the article

Context and Motivation

- Computers are everywhere, but computer literacy still a rare ability
- Computer Science Education Research (CSER) $\rightsquigarrow$ Improve teaching quality
- Focus restrictions here: teaching programming to 14-18 years old students
- Question: what do the teachers need to know to be good teachers
- Possible Long Term Goals:
  - Write a manual to help teachers to improve
  - Come up with a method to evaluate and diagnose the teachers abilities

What do good teachers know? What's missing to bad ones?

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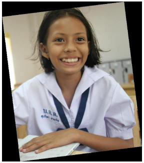
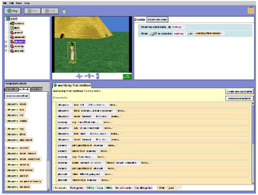
What do good teachers know? What's missing to bad ones?

- The students
- Topics Material
- Teaching Methods
- . . .



...And that, in simple terms, is how you increase your ranking on search engines."



Programming Education

What is Programming (as in Software Development) anyway?

- Wikipedia: Process of writing, testing, debugging/troubleshooting, and maintaining the source of code of computer programs
- Can be broadened: Ability to solve complex problems in a top-down approach
- Hard task: Level of programming understanding tested to be low after 2 years
- But pedagogy helps to some extends (remember of Papert's Logo, 1980)

Which Programming Language?

- Interestingly, this question is completely evacuated by the authors:

> *We will not refer to specific Programming Languages (e.g., Java, Python, etc.), because we consider these as a mean/tool to achieve the teaching of Programming. Secondary school students should be taught programming concepts independent of specific applications and programming languages*
> *(Stephenson et al., 2005; Szlàvi and Zsakò, 2006).*

Pedagogical Content Knowledge

What does PCK mean?

- Concept introduced by Shulman in 1989:

> *The ways of representing and formulating the subject*
> *that make it comprehensible to others*

- Knowing how to program $\not\Rightarrow$ Being able to teach programming (even $\not\Leftarrow$;)
- Combines knowledge of the contents (topics) to knowledge of the pedagogy

What can be PCK?

- Teachers represent and formulate content, so that comprehension can occurs
- Different learners may have different learning styles

⇒ Teachers need a real armamentarium of alternative forms of representation

- It often comes with years of teaching experience (cf. folk pedagogy)

- Rq: PCK can be *general* (domain wide) or *personal* (of a given teacher)
  Personal beliefs on the topic influence the teaching and thus the PCK.

Problem Statement & Overall Methodology

Main Goal: Uncover the PCK of Informatics

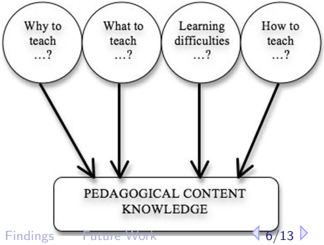
- The authors briefly mention several similar works (see article)
- Portraying the PCK of informatics is still a starting effort

What is out of focus?

- Pedagogy covers a much wider area: student's motivation, gender issues, etc.
- The focus here is on teachers, not on anything else

Methodology

- Use Grossmann's reformulation of PCK (1989, 1990) thru 4 questions:
- Easier way to define PCKs
- Simply answer four questions
- Helps defining the PCK, not discovering them
- Here: lit. review, starting in Google Scholar



So, Why Teach Programming?

- The question should be understood from the teacher perspective
- In particular, we don't speak of student motivation here

To teach powerful problem-solving/design/thinking strategies

- Find a solution, communicate it to the machine, using syntax and grammar
- Ability to split the problem in sub-problems & propose generic solutions
- Decomposition and Generalization reusable elsewhere (maths but also real life)

Improve rigorous communication abilities

- Interacting with an unintelligent machine improves natural language skills
- Rigorous thinking and Debugging reusable elsewhere (maths but also real life)

Technological Mastery & Deepest understanding of scientific disciplines

- Mastering the computer shouldn't be occluded, of course
- New subject mixing Linguistics, Maths, Philosophy, etc. under a new light

What should be Taught?

Programming Knowledge

- Core of programming: problem solving and creating a program as solution
- Two kind of knowledges: Program generation and Program comprehension
  1. Problem analyze; algorithmic solution; translation into program code
  2. Demonstrate an understanding of how a given program works

Program Knowledge (Tactical Programming)

- Data: Variable, data types (procedural); Object, attributes, actions (OOP)
- Instructions: Control Structures, subroutines; Interacting objects and Methods
- Syntax: Language-specific rules how what you can write and how

Modularity and Abstraction (Programming Strategies)

- Primitive expressions: the simplest expressible entities in a language
- Means of combination by which compound elements are built from simpler ones
- Means of abstraction giving name to compounds to manipulate them as units

Program Semantic

- Programs written with different syntax can perform the same semantic task

What are the Learning Difficulties? (1/2)

Programming is a really difficult task

- Correct program often result of an unexpected surprise to beginners

DuBoulay (1989)

- Orientation: Finding out what the benefits to learn to program are;
- Notional Machine: Properties of the machine that one is learning to control; Behavioral relations between notional and physical machine
- Notation: Aspects of the various formal languages (syntax and semantics)
- Structures: Schema or plans to use for small-scale goals (e.g., using a loop)
- Pragmatics: Specify, develop, test and debug programs with available tools

Students' misconceptions may lead to conceptual bugs (Pea 1986)

- Superbug: Some students converse with a computer as if it was a human
- Paralellism bug: several lines active or known by the computer at same time
- Intentionality bug: assume computers can go beyond the information given
- Egocentrism bug: don't do what I say, do what I mean!

What are the Learning Difficulties? (2/2)

Paradigm Shift

- When teaching several paradigms together (procedural and OO)
- When switching between paradigms (in particular proc $\rightarrow$ OO, not $\leftarrow$)

Problem Solving Skills

- Limited point of view lead to partial or erroneous solutions
- Difficulties to translate mental intuitions in a communicative way

Issues with the semantic

- Combining program parts into working solution (expr, statmt, ctrl struct . . .)
- Debugging: understanding the actual semantic of a given code

Issues with the syntax

- Choosing a programming language with complex syntax $\rightsquigarrow$ extra difficulty

How should the Topic be Taught? (1/2)

- No unique solution, but an armamentarium of tools, methods and tricks
- First, use a *simple* language so that students focus on the semantic

Improve Algorithmic Thinking

- Write simple programs and then combine them (receipts for a cooking machine)
- Give many carefully chosen algorithmic problems (Futschek 2006, Romeike 2008)
- This could even be done w/o computers, but translating remains difficult

Possible Chain for Learning (Linn and Dalbey, 1989)

- From program comprehension to program generation, with three links
- Language features: adapt a provided program to do smth slightly different
- Design skills: how to combine features into programs
    - Templates: stereotypical patterns of code
    - Procedural skills: combine toward new problems (plan, test, reformulate)
- General problem-solving skill: Solve problems using new formal systems
  Such as new a programming language

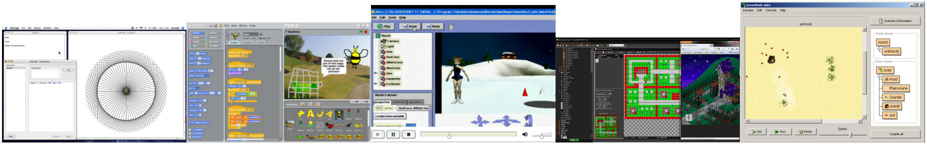
How should the Topic be Taught? (2/2)

Introducing the Notional Machine

- Some model or description of the machine $\rightsquigarrow$ framework for understanding
- Kind of model depends on students' age, background and studies

Engaging the students through adapted environments

- Many environments to introduce programming in active & motivating way
- Logo (problem solving), Scratch (no syntax issue), Alice, Greenfoot, Gamemaker
- Justified by Piaget's model of children's learning:
  Students build their own intellectual structures, if provided with right material
- Teachers provide right support/stimuli/learning material to use with tools
- But no such environment contain all structures & topics needed



Conclusion and Future work

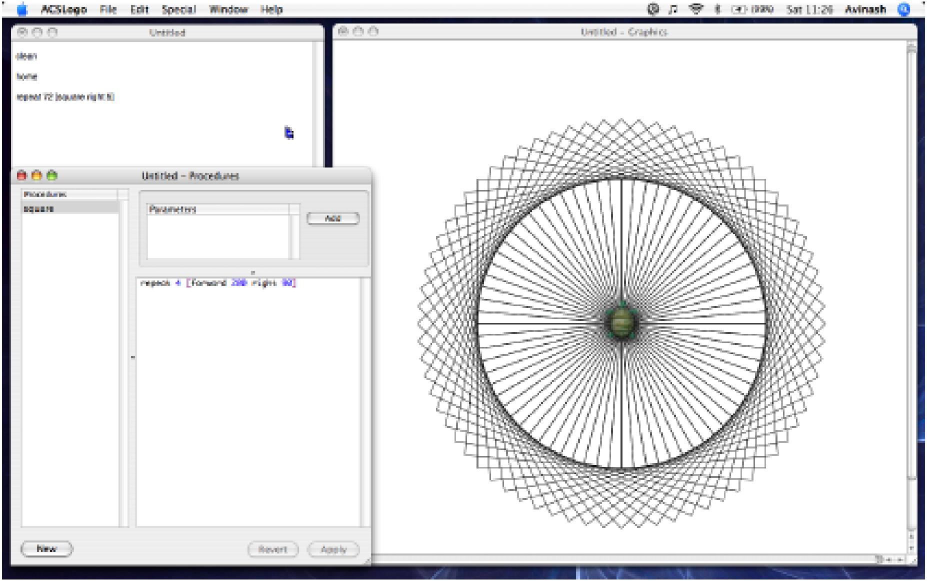
This work is part of a PhD

1. Literature review (the journal article)
2. Applies CoRes methodology in workshop with practitioners
   Identify Programming's Big Ideas and their own detailed PCK
3. Assess how a manual could help teachers with low PCK, assess Teachers' PCK

CoRes (Content Representations)

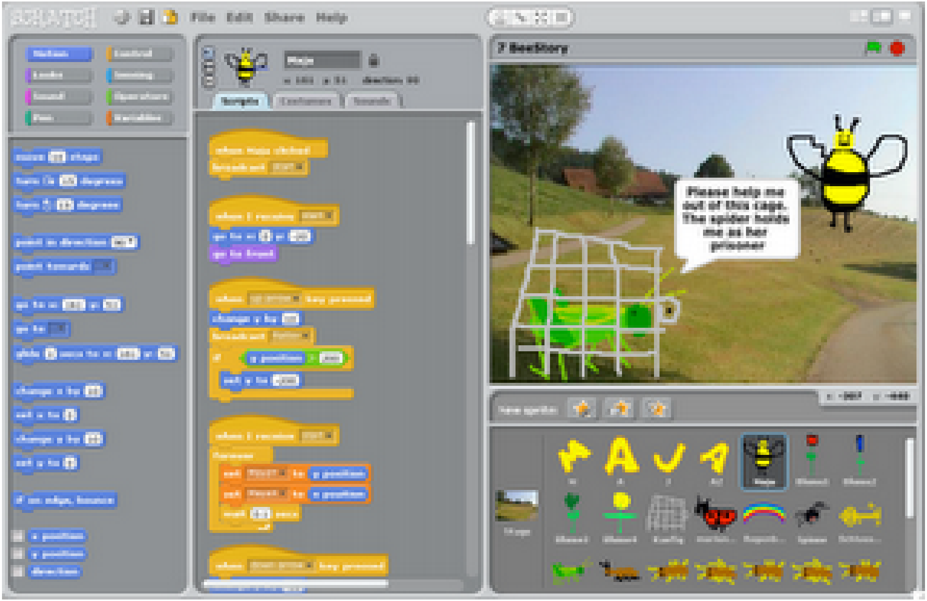
- Research instrument deployed to discover chemistry's PCK in Australia in 2001
- Enumerate the Big Ideas (BI) of the domain, and ask 8 questions for each:
  - a. Why is it important for the students to know this BI?
  - b. What do you intend the students to learn about this BI?
  - c. What else *you* might know about this BI (students don't need to know yet)?
  - c. What are difficulties/ limitations connected with the teaching of this Big idea?
  - c. What do you think students need to know in order for them to learn this BI?
  - c. Specific ways of ascertaining students understanding or confusion around BI?
  - d. Which factors influence your teaching of this Big idea?
  - d. What are teaching methods (any particular reasons for using these)?

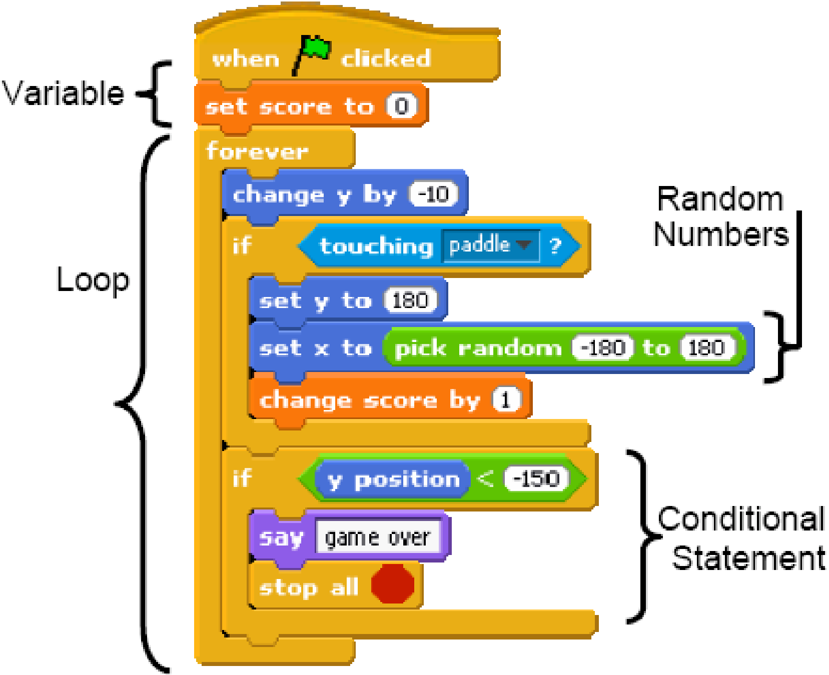
(see Research Report `http://www.tue.nl/fileadmin/content/universiteit/Over_de_universiteit/Eindhoven_School_of_Education/Onderzoek/Projecten_promovendi/Mara_Saeli_SPJZ_Technical_Report.pdf`)



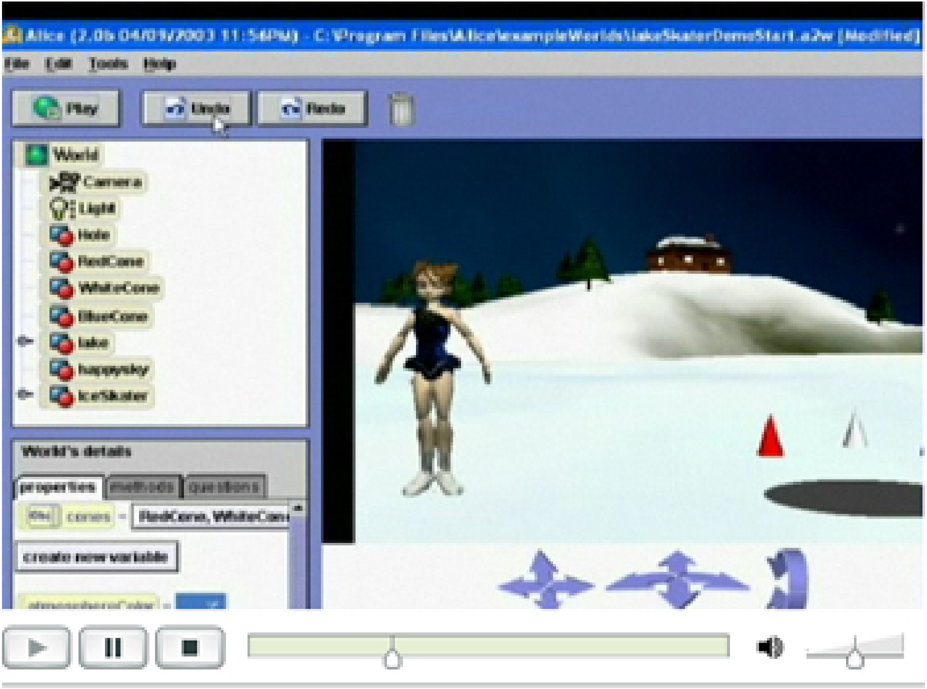
```
clean
home
repeat 72 [square right 5]
```

```
repeat 4 [forward 200 right 90]
```

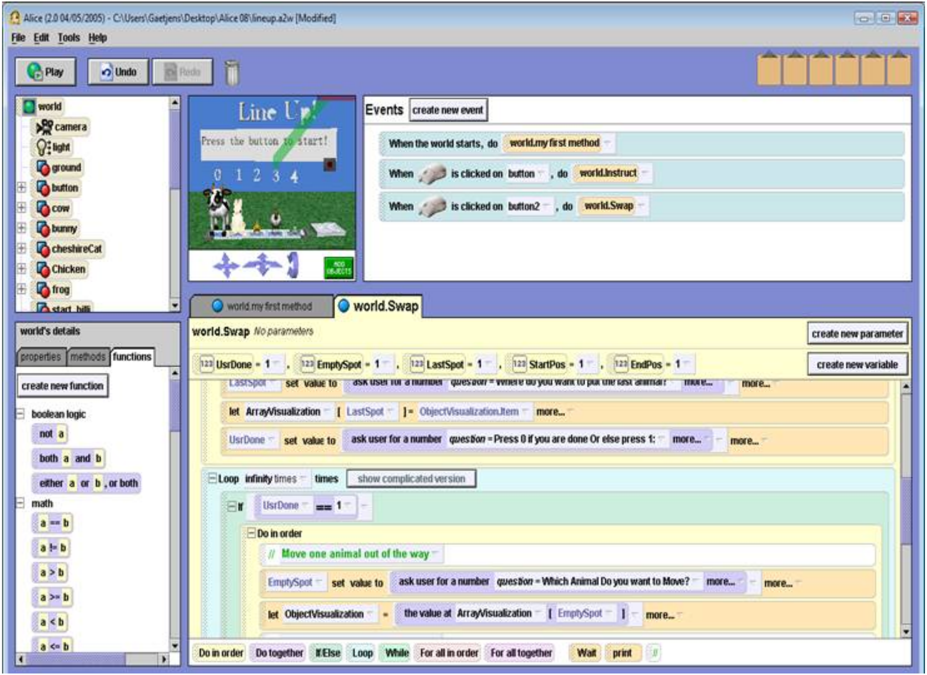

File
Edit
Share
Help
Maja
7 BeeStory
Please help me out of this cage. The spider holds me as her prisoner
Scripts
Stage



```
when clicked
set score to 0
forever
    change y by -10
    if touching paddle ?
        set y to 180
        set x to pick random -180 to 180
        change score by 1
    if y position < -150
        say game over
        stop all
```



cones = RedCone, WhiteCon



When the world starts, do world.my first method

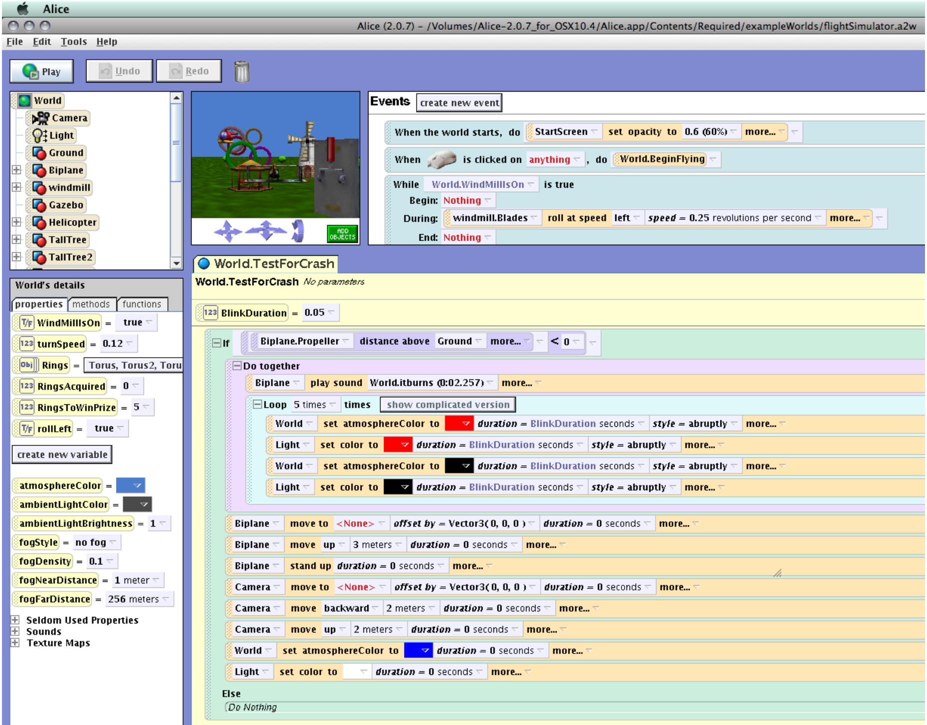
When is clicked on button , do world.Instruct

When is clicked on button2 , do world.Swap

world.Swap *No parameters*

```
123 UsrDone = 1 , 123 EmptySpot = 1 , 123 LastSpot = 1 , 123 StartPos = 1 , 123 EndPos = 1

    LastSpot set value to ask user for a number question = Where do you want to put the last animal? more... more...
    let ArrayVisualization [ LastSpot ]= ObjectVisualization.Item more...
    UsrDone set value to ask user for a number question = Press 0 if you are done Or else press 1: more... more...
  Loop infinity times times
    If UsrDone == 1
      Do in order
        // Move one animal out of the way
        EmptySpot set value to ask user for a number question = Which Animal Do you want to Move? more... more...
        let ObjectVisualization = the value at ArrayVisualization [ EmptySpot ] more...
```



World
- Camera
- Light
- Ground
- Biplane
- windmill
- Gazebo
- Helicopter
- TallTree
- TallTree2

World's details

WindMillIsOn = true
turnSpeed = 0.12
Rings = Torus, Torus2, Toru
RingsAcquired = 0
RingsToWinPrize = 5
rollLeft = true

atmosphereColor =
ambientLightColor =
ambientLightBrightness = 1
fogStyle = no fog
fogDensity = 0.1
fogNearDistance = 1 meter
fogFarDistance = 256 meters

Seldom Used Properties
Sounds
Texture Maps

Events

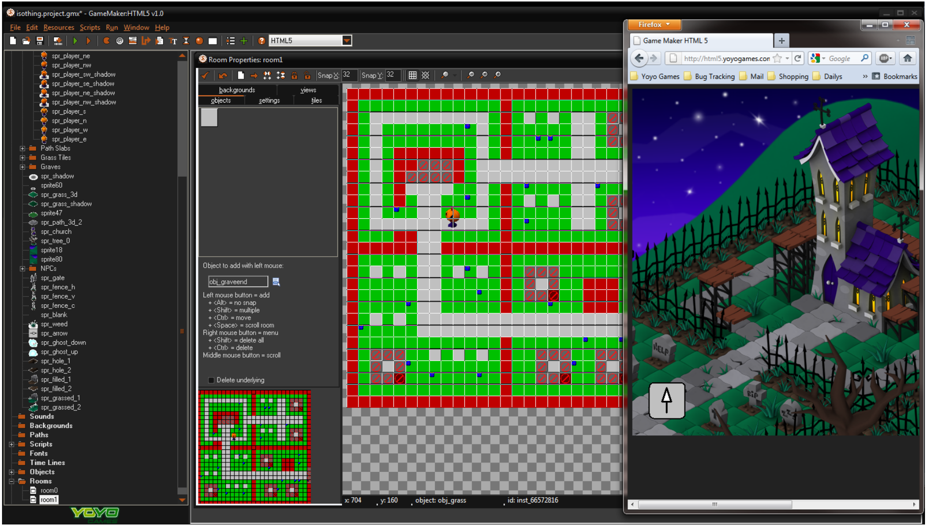
```
When the world starts, do  StartScreen set opacity to 0.6 (60%) more...
When  is clicked on anything , do World.BeginFlying
While World.WindMillIsOn is true
  Begin: Nothing
  During: windmill.Blades roll at speed left speed = 0.25 revolutions per second more...
  End: Nothing
```

World.TestForCrash

```
World.TestForCrash No parameters

BlinkDuration = 0.05

If  Biplane.Propeller distance above Ground more... < 0
  Do together
    Biplane play sound World.itburns (0:02.257) more...
    Loop 5 times times
      World set atmosphereColor to  duration = BlinkDuration seconds style = abruptly more...
      Light set color to  duration = BlinkDuration seconds style = abruptly more...
      World set atmosphereColor to  duration = BlinkDuration seconds style = abruptly more...
      Light set color to  duration = BlinkDuration seconds style = abruptly more...
  Biplane move to <None> offset by = Vector3( 0, 0, 0 ) duration = 0 seconds more...
  Biplane move up 3 meters duration = 0 seconds more...
  Biplane stand up duration = 0 seconds more...
  Camera move to <None> offset by = Vector3( 0, 0, 0 ) duration = 0 seconds more...
  Camera move backward 2 meters duration = 0 seconds more...
  Camera move up 2 meters duration = 0 seconds more...
  World set atmosphereColor to  duration = 0 seconds more...
  Light set color to  duration = 0 seconds more...
Else
  Do Nothing
```



Snap X: 32 Snap Y: 32

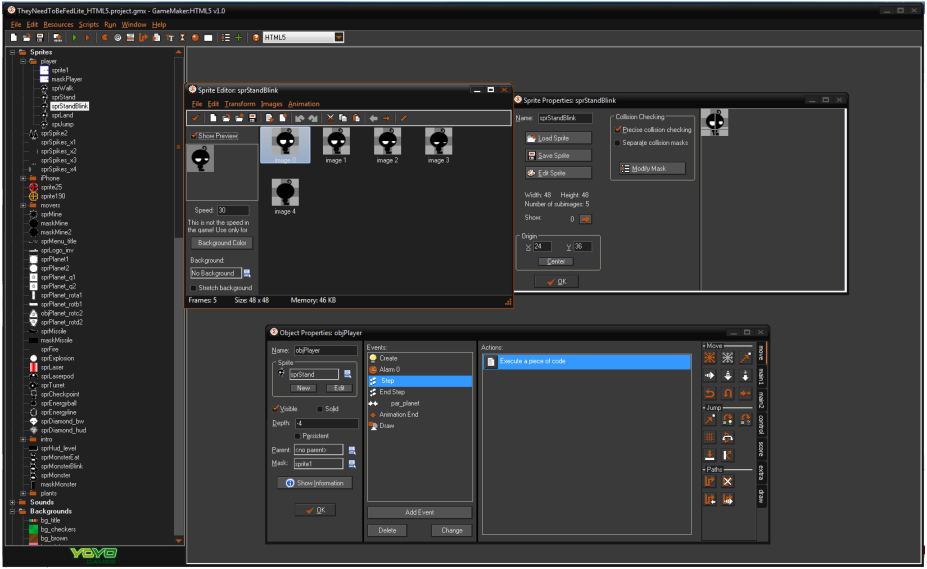
Object to add with left mouse:

obj_graveend

Left mouse button = add
+ <Alt> = no snap
+ <Shift> = multiple
+ <Ctrl> = move
+ <Space> = scroll room
Right mouse button = menu
+ <Shift> = delete all
+ <Ctrl> = delete
Middle mouse button = scroll

☐ Delete underlying

x: 704 y: 160 object: obj_grass id: inst_66572816



☑ Show Preview

Speed: 30

This is not the speed in the game! Use only for

Background: No Background

☐ Stretch background

Frames: 5 Size: 48 x 48 Memory: 46 KB

Name: sprStandBlink

☑ Precise collision checking

☐ Separate collision masks

Width: 48 Height: 48

Number of subimages: 5

Show: 0

X 24 Y 36

Name: objPlayer

Sprite: sprStand

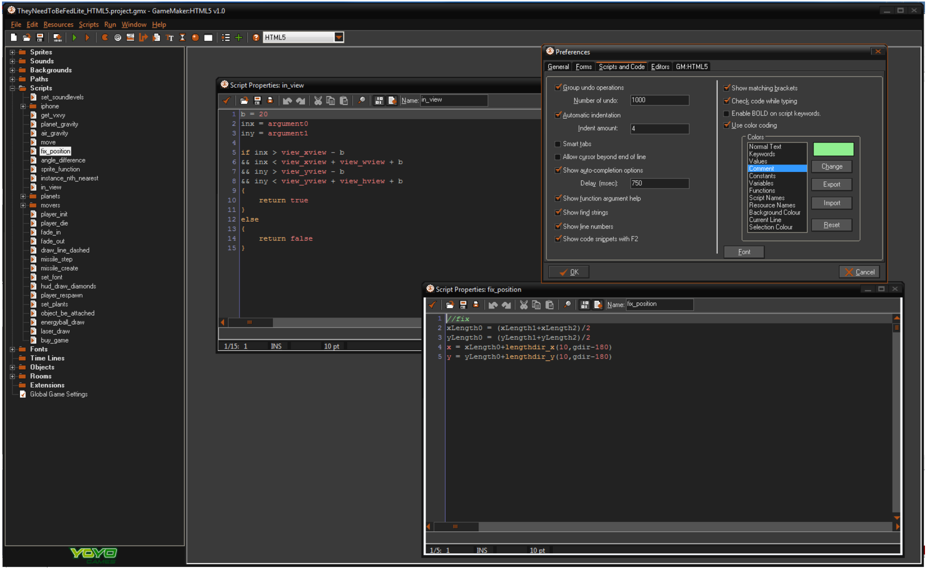
☑ Visible ☐ Solid

Depth: -4

☐ Persistent

Parent: <no parent>

Mask: sprite1



Script Properties: in_view

Name: in_view

```
b = 20
inx = argument0
iny = argument1

if inx > view_xview - b
&& inx < view_xview + view_wview + b
&& iny > view_yview - b
&& iny < view_yview + view_hview + b
{
    return true
}
else
{
    return false
}
```

1/15: 1 INS 10 pt

Preferences

☑ Group undo operations

Number of undo: 1000

☑ Automatic indentation

Indent amount: 4

☐ Smart tabs

☐ Allow cursor beyond end of line

☑ Show auto-completion options

Delay (msec): 750

☑ Show function argument help

☑ Show find strings

☑ Show line numbers

☑ Show code snippets with F2

☑ Show matching brackets

☑ Check code while typing

☐ Enable BOLD on script keywords.

☑ Use color coding

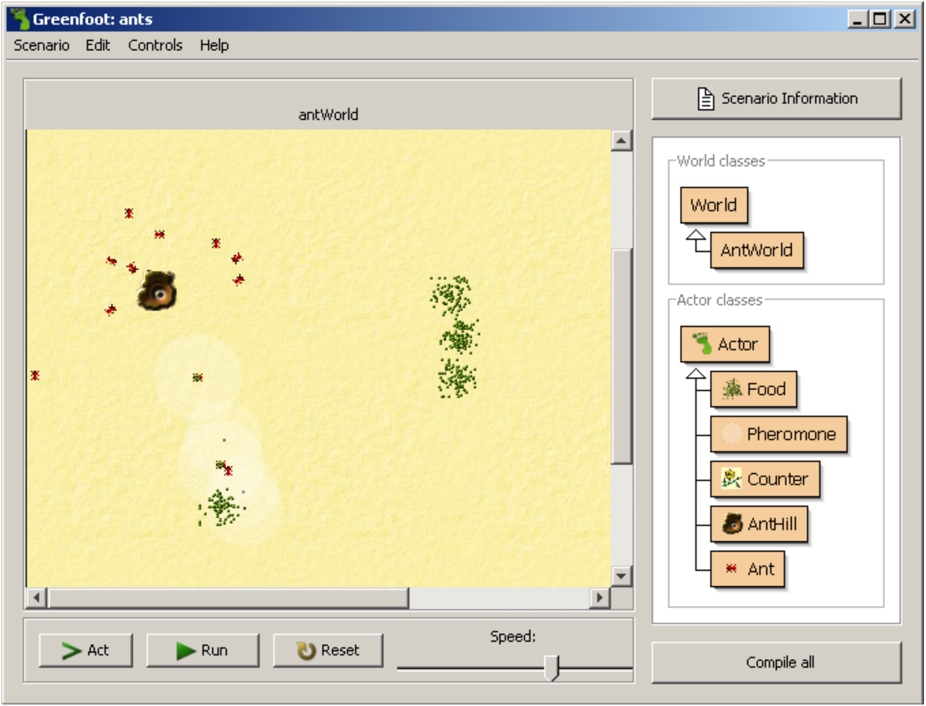
Colors: Comment 🟩

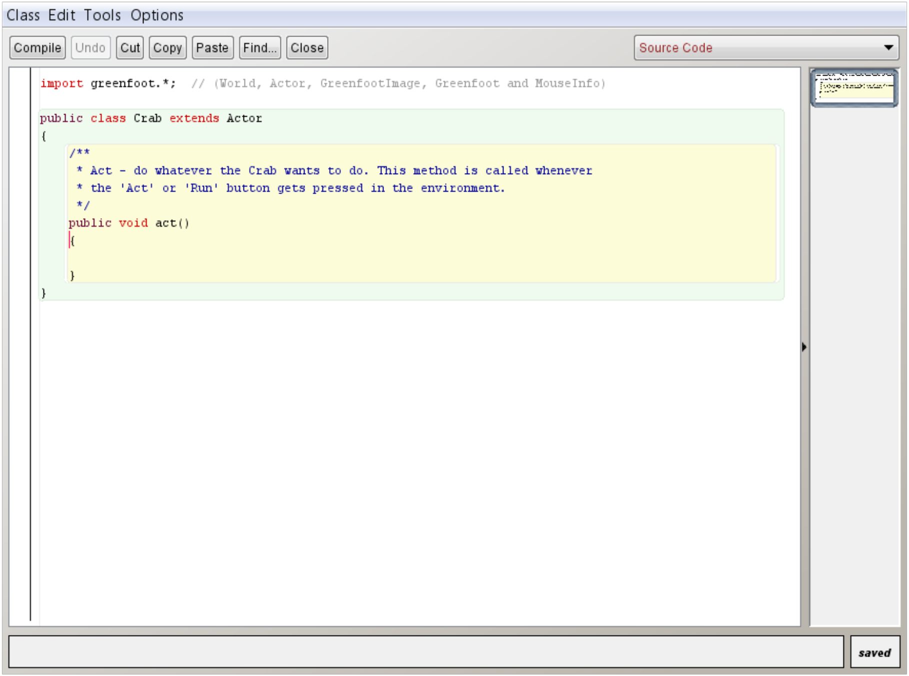
Script Properties: fix_position

Name: fix_position

```
//fix
xLength0 = (xLength1+xLength2)/2
yLength0 = (yLength1+yLength2)/2
x = xLength0+lengthdir_x(10,gdir-180)
y = yLength0+lengthdir_y(10,gdir-180)
```

1/5: 1 INS 10 pt


Greenfoot: ants
Scenario
Edit
Controls
Help
antWorld
Scenario Information
World classes
World
AntWorld
Actor classes
Actor
Food
Pheromone
Counter
AntHill
Ant
Act
Run
Reset
Speed:
Compile all



```
import greenfoot.*;  // (World, Actor, GreenfootImage, Greenfoot and MouseInfo)

public class Crab extends Actor
{
    /**
     * Act - do whatever the Crab wants to do. This method is called whenever
     * the 'Act' or 'Run' button gets pressed in the environment.
     */
    public void act()
    {

    }
}
```