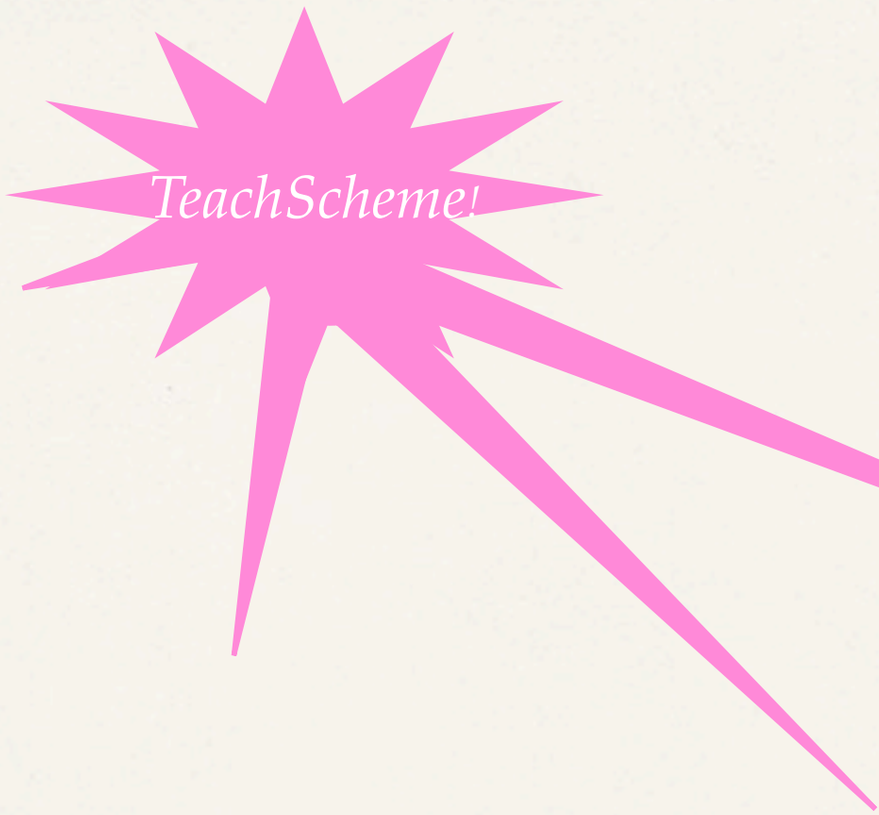
The *Teach Scheme!* Project

Matthias Felleisen (PLT)
Northeastern University
Boston, MA

The *Teach Scheme, NOT* Project



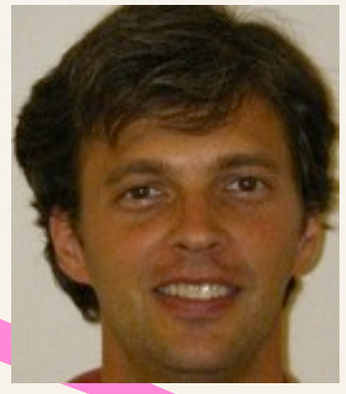
- ~ 15 years of outreach
- ~ 10 sites
- ~ 100ish research papers
- ~ 1,000ish teachers trained
- ~ 10,000s students in reach
- ~ 1,000,000 downloads (unique IP)

The *Teach Scheme, NOT* Project

January 26, 1995

Shriram Krishnamurthi
(Brown)

TeachScheme!



Matthew Flatt
(Utah)

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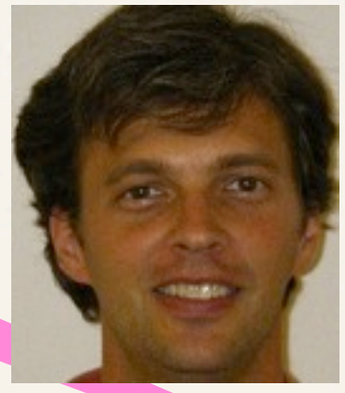

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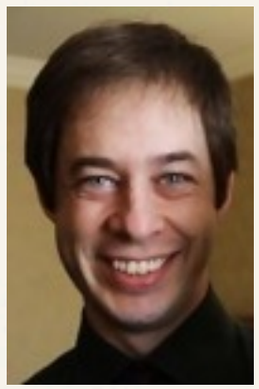

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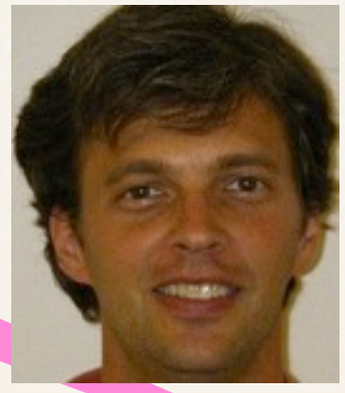

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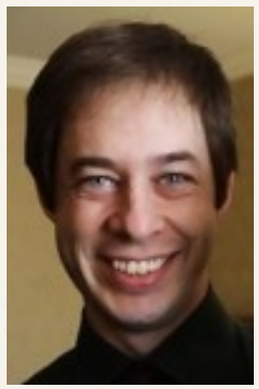

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Kathi Fisler
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The *TeachScheme*! Idea

typical high school:
1,000 or 2,000 or 3,000
and more students

typical CS courses in high school:
20, 40, perhaps 80 students

The *TeachScheme*! Idea

Why can't we have 1,000 or 2,000 or 3,000 or **all students** in our introductory CS course?

typical high school: 1,000 or 2,000 or 3,000 and more students

Why can't we show them how **beautiful** CS is and have them **benefit** from it all?

typical CS courses in high school: 20, 40, perhaps 80 students

The *TeachScheme!* Idea

Observation: Teaching novices how to program in a professional language does not do computer science justice. Indeed, what we have seen in the last gfew decades is that it drives students away.

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Idea: Teaching the ideas of programming with mathematics demonstrates the depth, breadth & beauty of computing. It also aligns our field with one of the three important R's in the education world.

The *TeachScheme!* Idea

Observation: Teaching novices how to program in a professional language does not do computer science justice. Indeed, what we have seen in the last gfew decades is that it drives students away.

Synthesis: We can start with one and smoothly reach the other.

Idea: Teaching the ideas of programming with mathematics demonstrates the depth, breadth & beauty of computing. It also aligns our field with one of the three important R's in the education world.

We can!

(1) program with mathematics

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(2) provide a smooth path all the way to "real" programming

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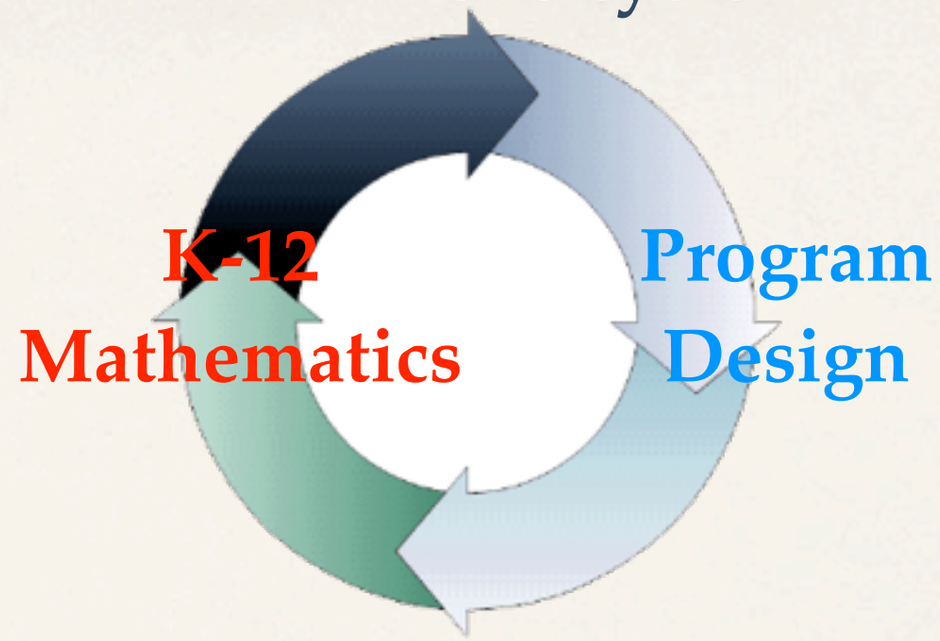
failures & challenges

We can!

A virtuous cycle



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failures &
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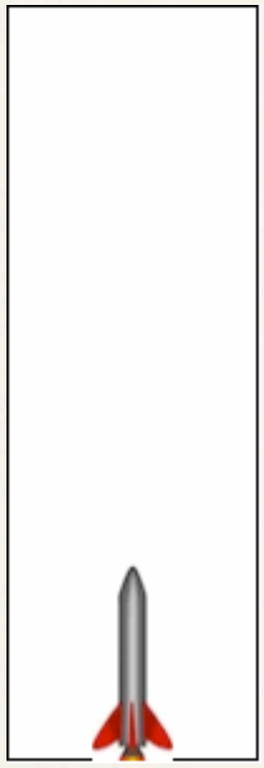
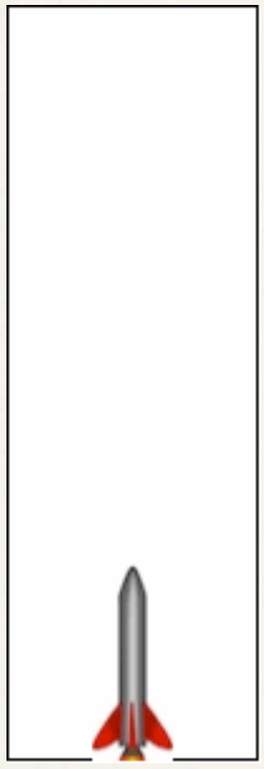
Programming with Mathematics for Fun

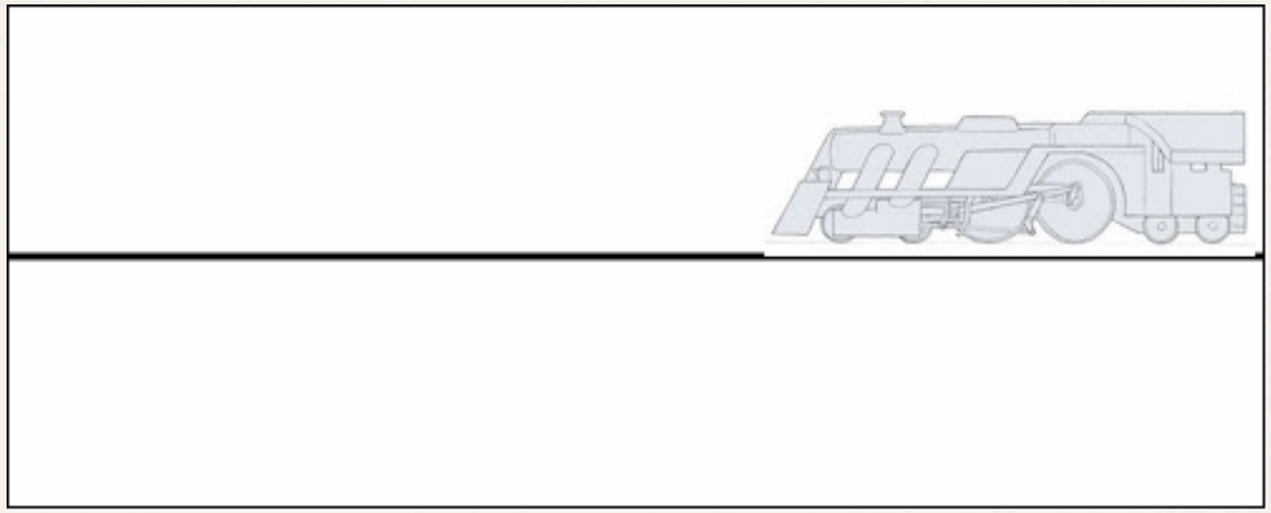
“Hello World” -- with mathematics

“Hello World” -- with mathematics



“Hello World” -- with mathematics





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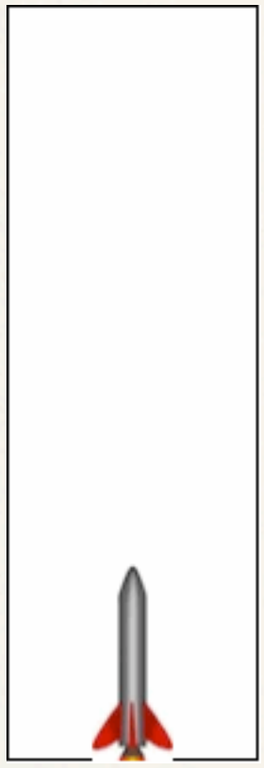
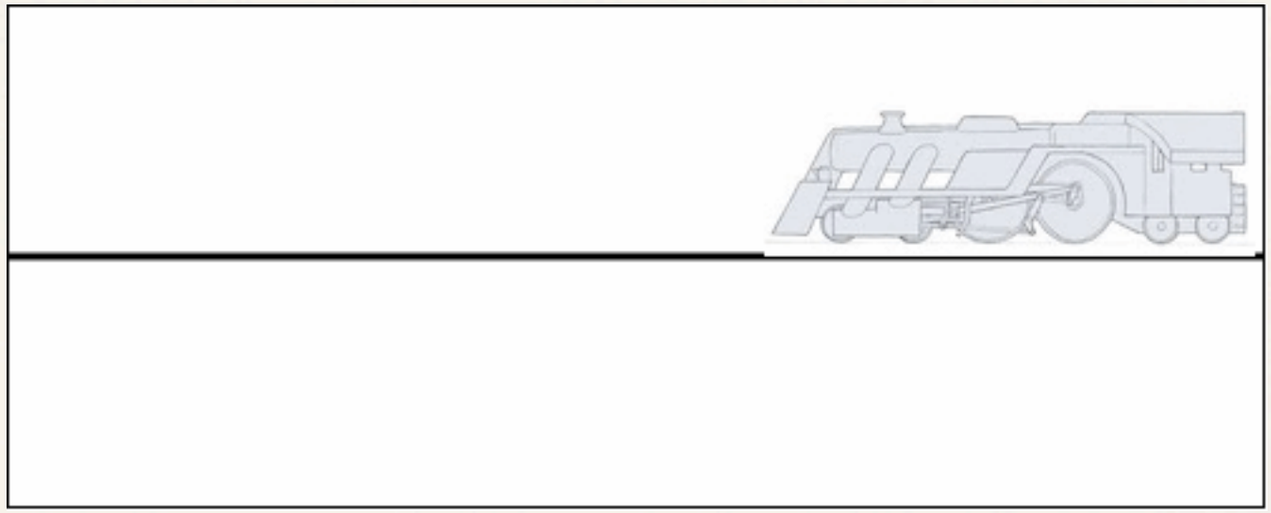
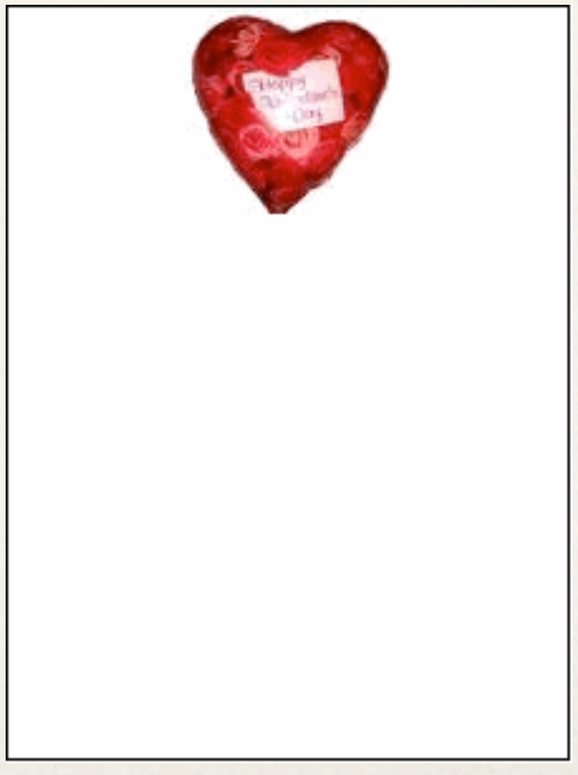






What do you need to get there?

Standard math problems, which students hate

Problem 1: A rocket lifts off from its launchpad at the constant speed of 7.5 ft per second. What height does it reach after 0 seconds, 1 second, 2 seconds, 3 seconds, *t* seconds?

Problem 2: A train leaves Dallas for Chicago and travels at the constant speed of 65 miles per hour. How far does it get in 0 hours, 1 hour, 1.5 hours, 2 hours, *h* hours?

Problem 3: A balloon drops from the ceiling of a convention center at the constant speed of 15 feet per second. How far does it drop in 0 seconds, 1 second, 2 seconds, *h* seconds?

What do you need to get there?

Tables, which students know

Problem 1: A rocket lifts off from its launchpad at the constant speed of 7.5 ft per second. What height does it reach after 0 seconds, 1 second, 2 seconds, 3 seconds, *t* seconds?

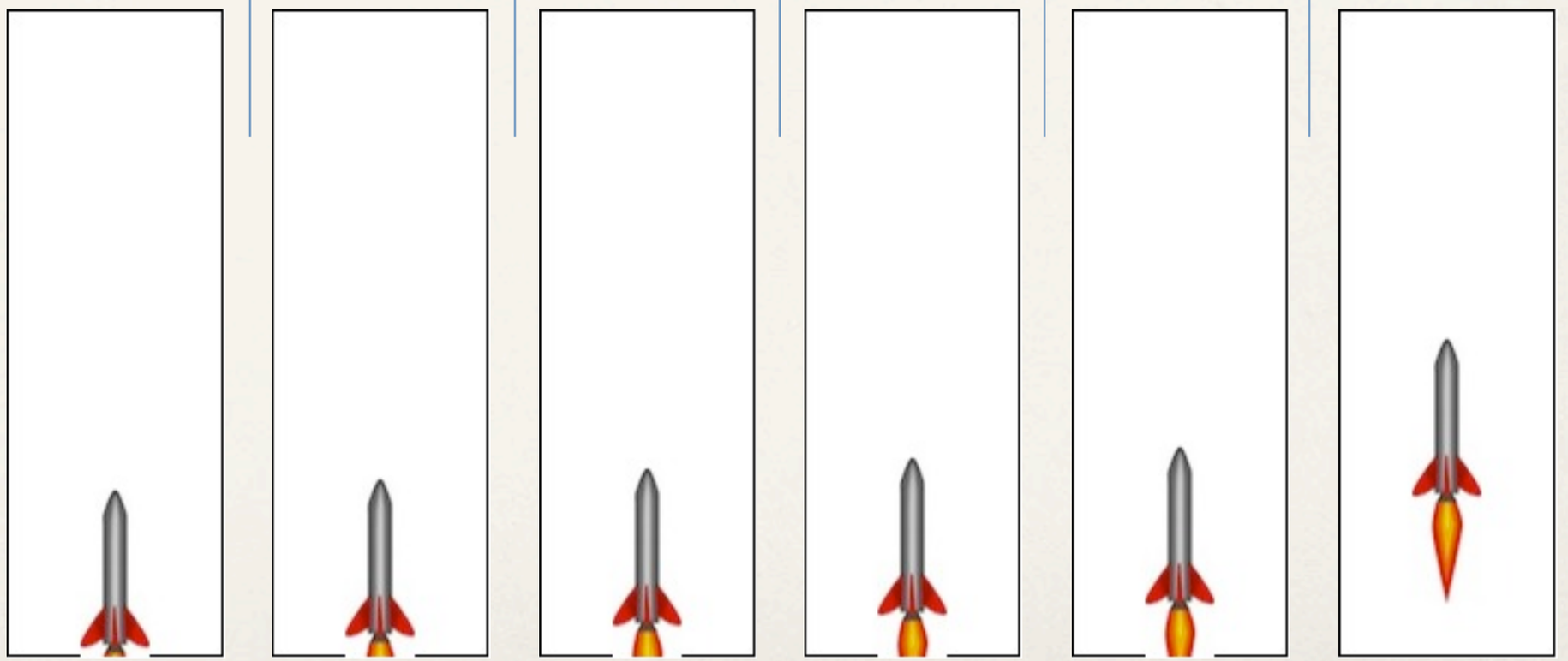
time	0	1	2	3	4	... t ...
height	0	7.5	15.0	22.5	30.0	y = 7.5 * t

What do you need to get there?

Images, which aren't a problem

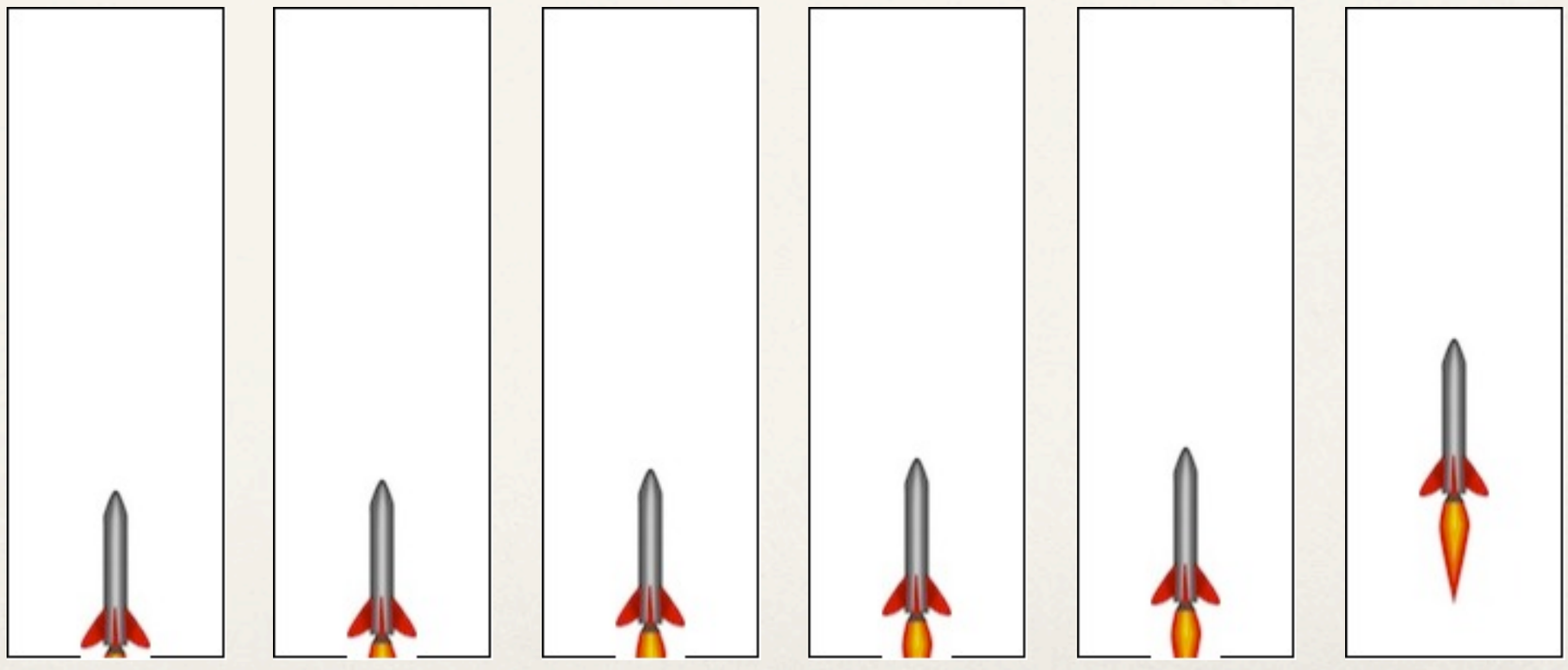
Problem 1: A rocket lifts off from its launchpad at the constant speed of 7.5 ft per second. What height does it reach after 0 seconds, 1 second, 2 seconds, 3 seconds, *t* seconds?

time	0	1	2	3	4	... t ...
height	0	7.5	15.0	22.5	30.0	y = 7.5 * t
sketch it						



What do you need to get there?

Imagination: what happens if you display ~30 images per second of this series?



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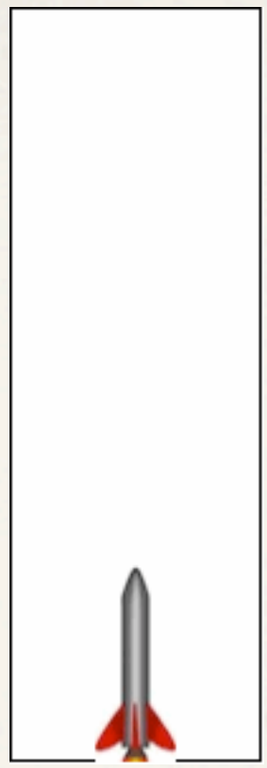

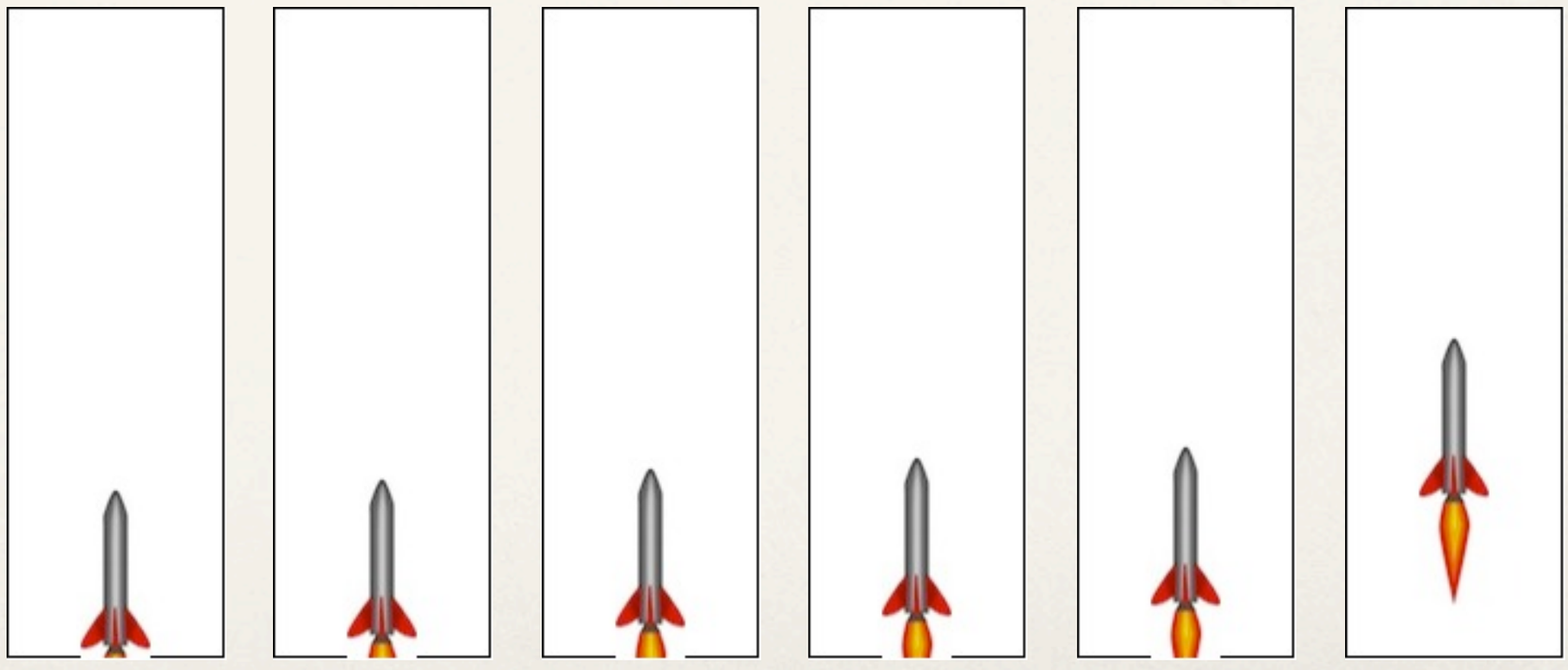

How do you get images into math?

The arithmetic of images:
images are like numbers

1 + 1 =

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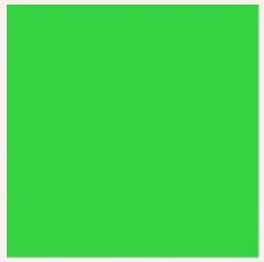
overlay

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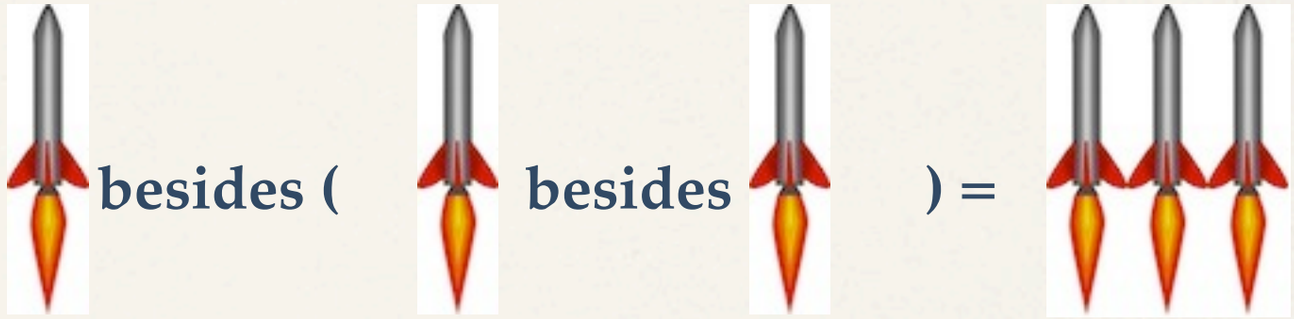

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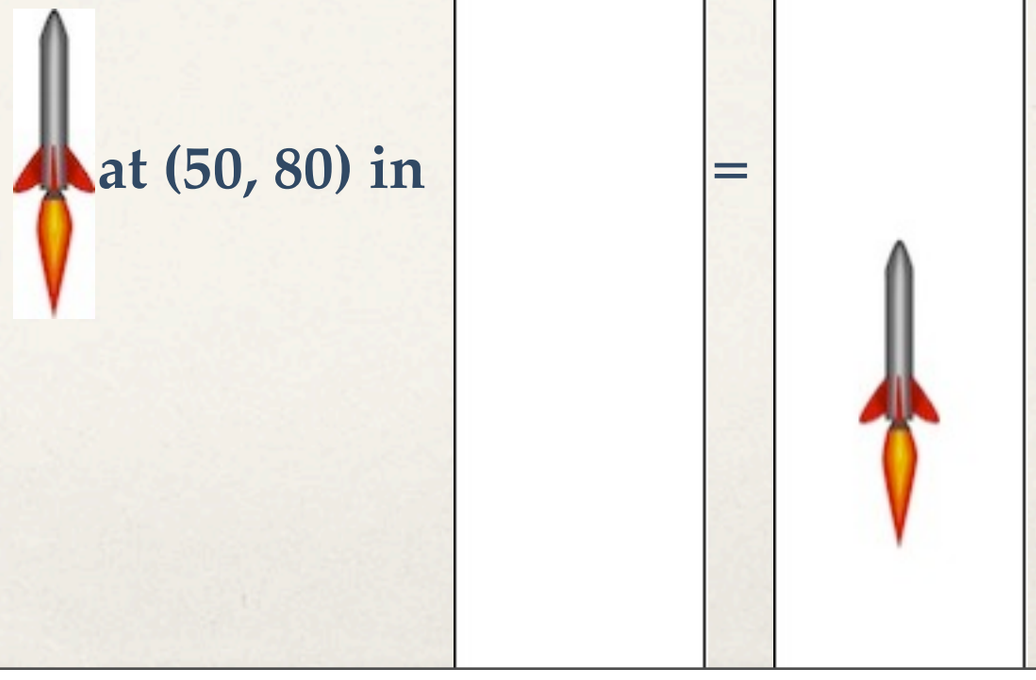
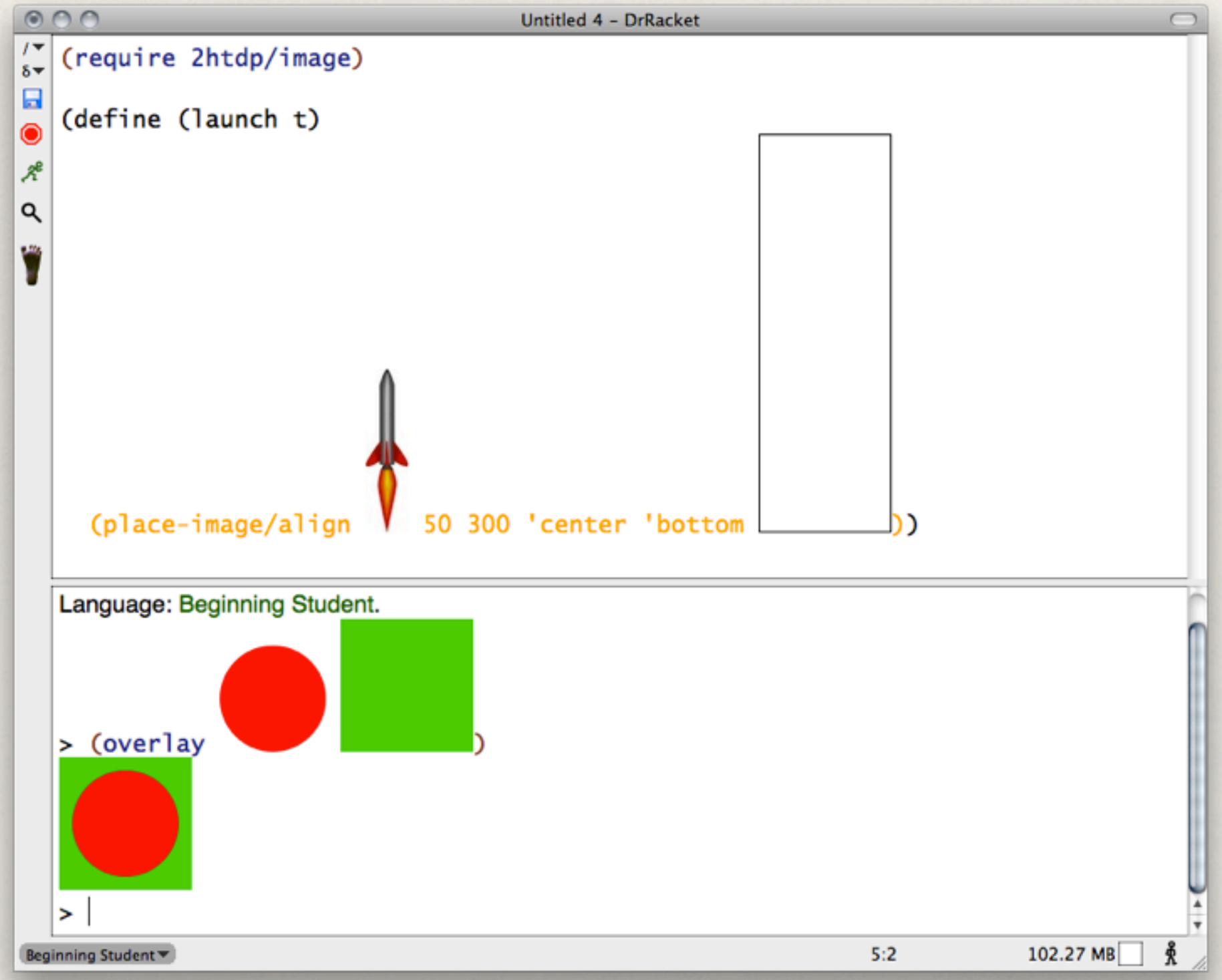
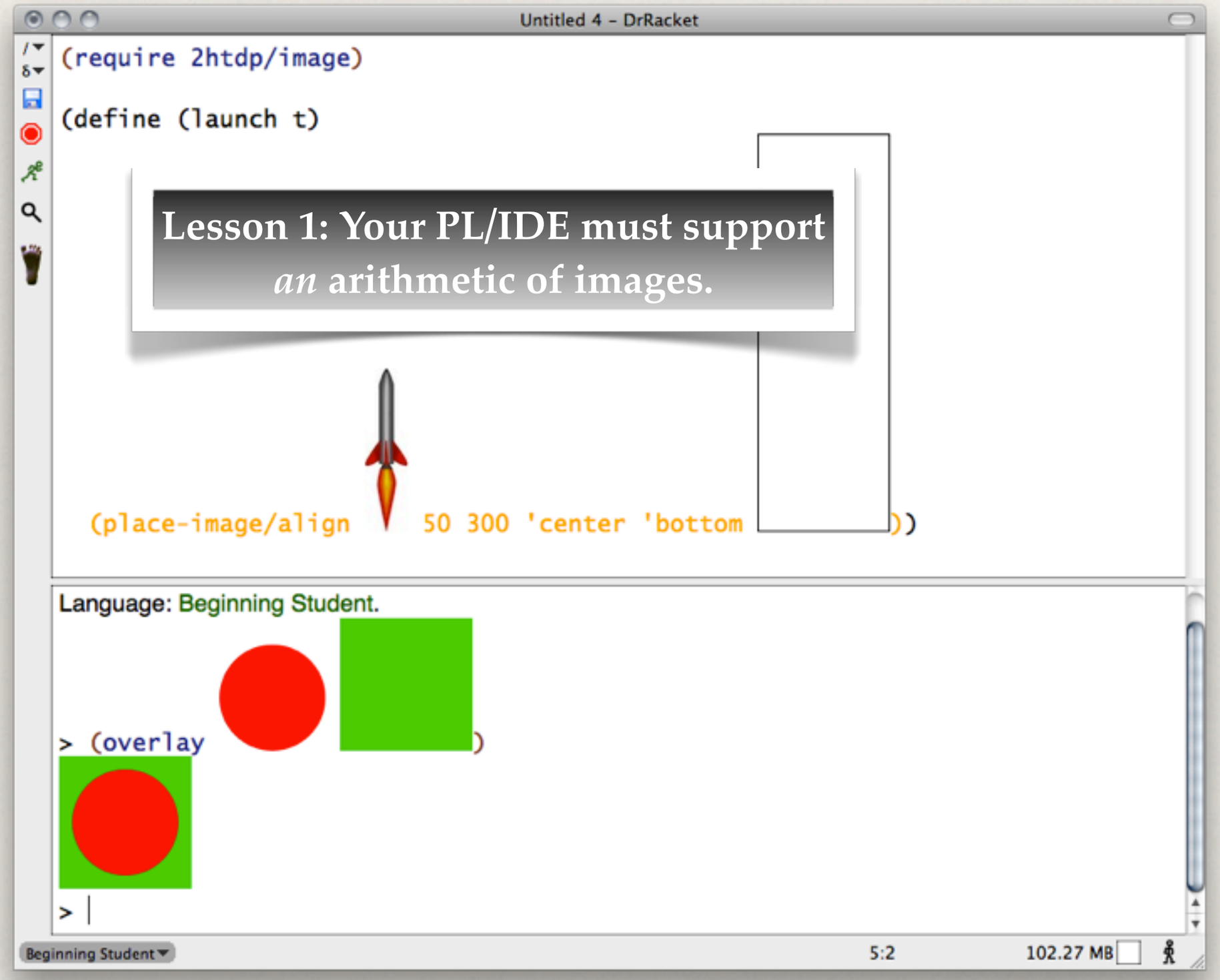


How do you get images into math: with DrRacket

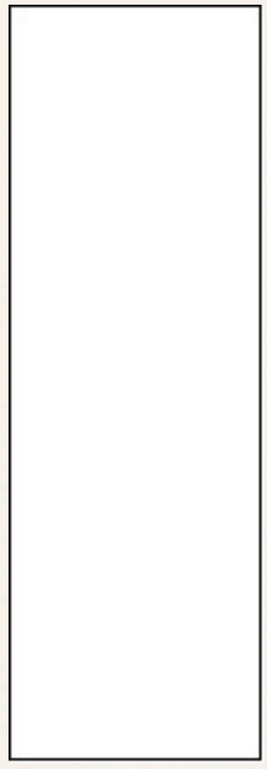


How do you get images into math: with DrRacket

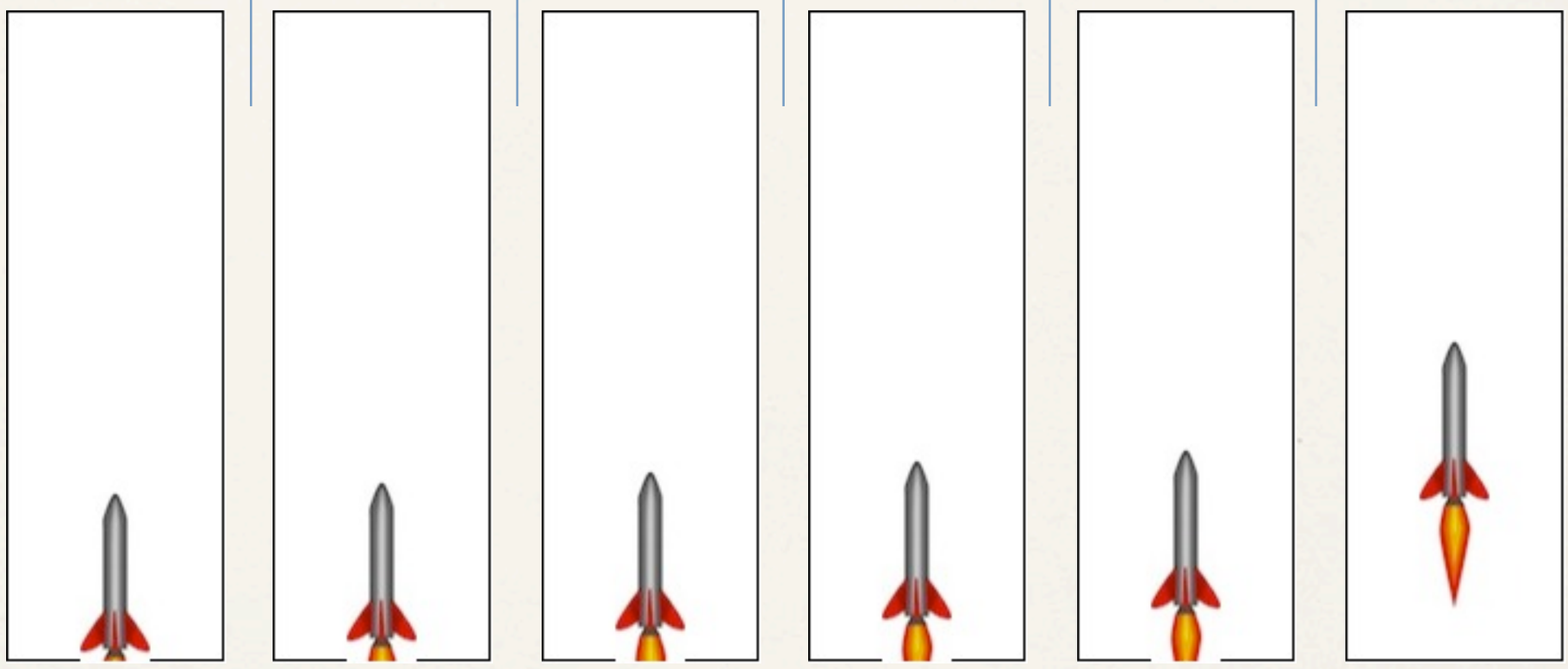


How do you get images into math?

Now add the usual bit of algebra, a plain function definition

launch(t) = place  at (50, 7.5 * t) in 

How do you get images into math?

time	0	1	2	3	4	... t ...
launch	*launch*(0)	*launch*(1)	*launch*(2)	*launch*(3)	*launch*(4)	
						

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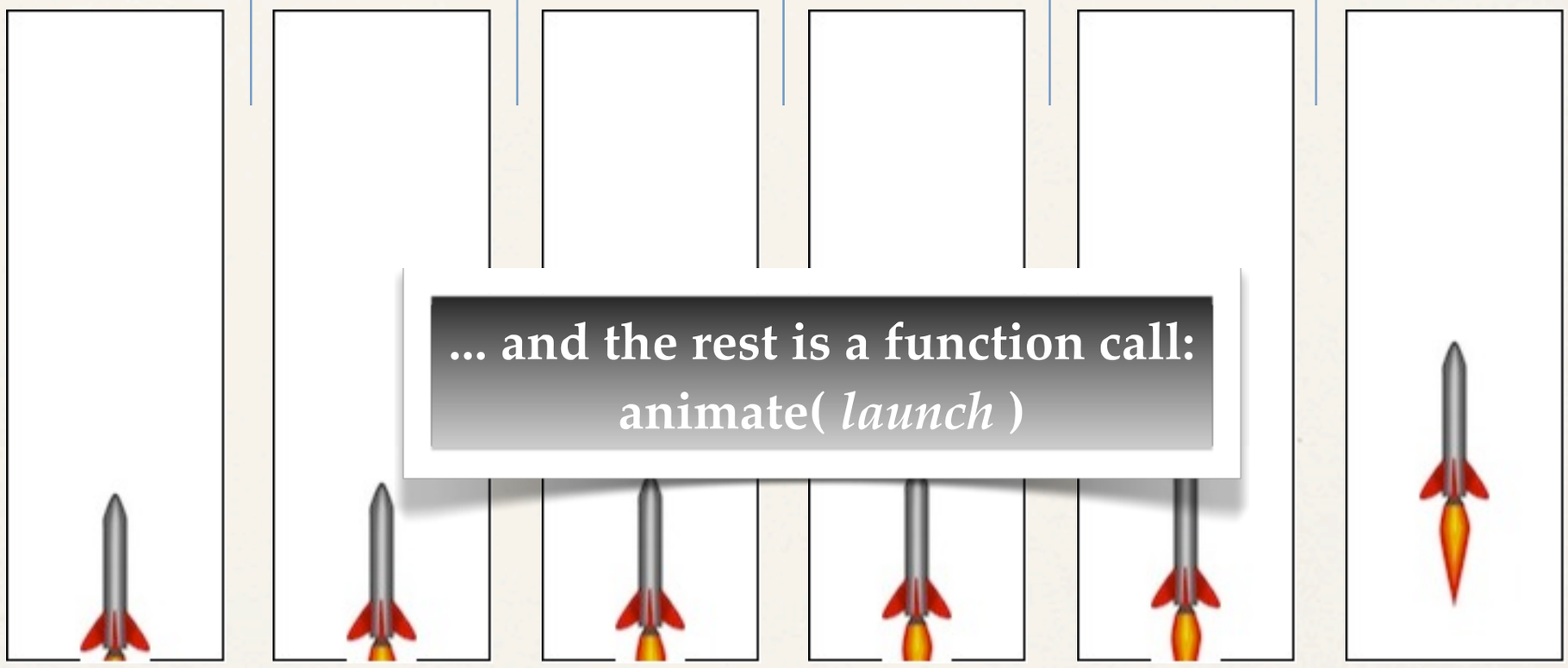

... and the rest is a function call:
animate(*launch*)

How do you get images into math?

some more detail:
describe the world and its actions

```
(define (animate stateToImage)
 (big-bang 0
   [on-tick add1]
   [to-draw stateToImage]))
```

How do you get images into math?

some more detail:
describe the world and its actions

```
(define (animate stateToImage)
 (big-bang 0
   [on-tick add1]
   [to-draw stateToImage]))
```

animate (*stateToImage*) is:

(1) initial state of the world is 0

state[0] = 0

(2) every time the clock ticks, add 1 to the state of the world

state[t+1] = state[t] + 1

(3) after every event, render the state of the world

***theImage* = *stateToImage*(state[t])**

How do you deal with *keyboard* and *mouse events* in math?

```
(define (game state0)
   (big-bang state0
     [on-tick time-handler]
     [on-key  key-handler]
     [to-draw image-renderer]))

;; World KeyEvent -> World
(define (key-handler current key)
  ...)
```

a video game is:

(1) initial state of the world is *something*

(2) every time the clock ticks,

compute the next *state from the* current *state*

(3) every time a key event happens,

compute the next *state from the* current *state & key event*

(4) every time a mouse event takes place,

compute the next *state from the* current *state & mouse event*

(5) after every event: *compute an image from the* current *state*

Do kids find this *exciting*? Do they *benefit* from it?

Yes! In a short time, kids write 80s-style video games *with middle school mathematics as PL.*

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Kids ask for more mathematics: conditional functions, geometry, trigonometry, pre-calculus concepts, and many more.

$$sign(x) = \begin{cases} +1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$$

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Their *performance* on all kinds of *mathematics exams improves.*

And many want more programming!

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```
-- structures
-- vectors
-- unions
-- lists
-- graphs
-- trees
```

And many want more programming!

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and yes,
function-consuming and
function-producing functions

And many want more programming!

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and yes,
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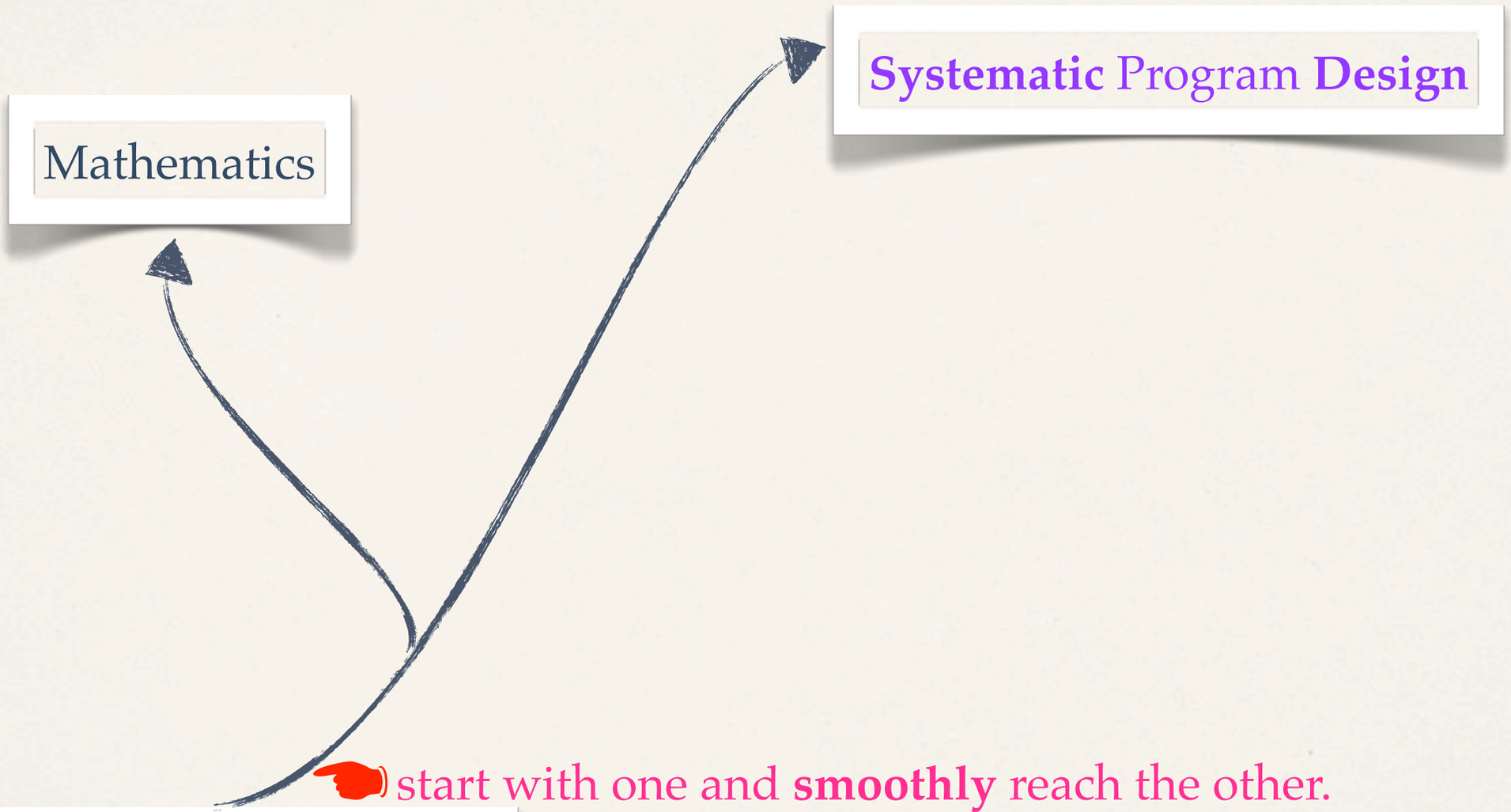
function-producing functions

plus
something like modules,
classes, objects, or other
organizational mechanisms

We got them hooked!



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fun programming with
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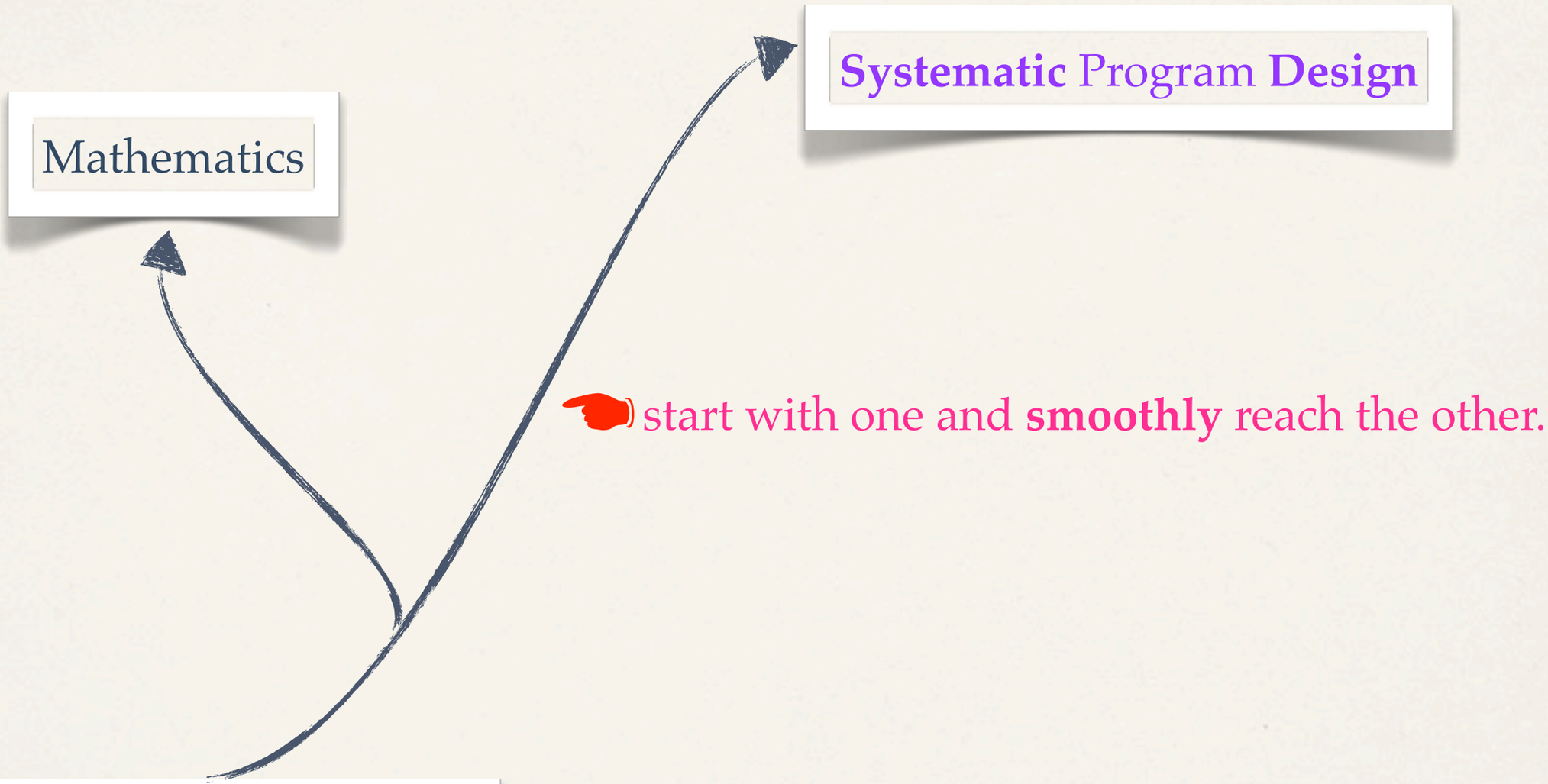

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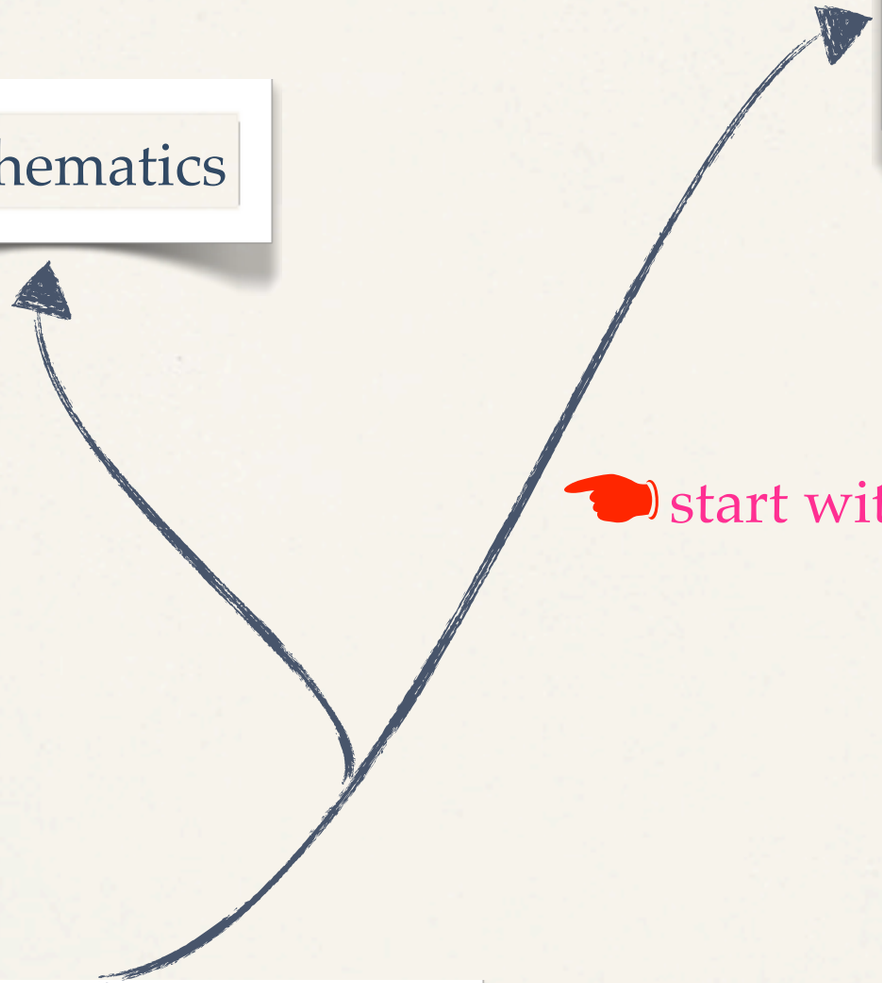
Mathematics

Systematic Program **Design**



☛ start with one and **smoothly** reach the other.

fun programming with "plain" **mathematics**

What's needed now:
(1) programming languages
(2) design recipes

Programming Languages Matter

Programming in ‘off-the-shelf’ languages

The year is 1995, Houston.
Michael Hunt & Karen North’s classrooms
C++ is the language *du jour*.

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```
void main() {
  double price_per_slice = 21.95 / 12;
  double total_due       = 0.0;
  int number_of_slices   = 0;

  cout << "how many slices did you eat?" << endl;
  cin >> number_of_slices;
  price_per_slice * number_of_slices  = total_due;
  cout << "your share is " << total_due << endl;
}
```

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}
```

lvalue expected here

Programming in 'off-the-shelf' languages

The year is 1995, Rice @ Houston.
Scheme is my language *of hope*.

```
(define (how-many a-list)
  (cond
    [(empty? a-list) 0]
    [else add1 (how-many (rest a-list))]))
```

```
> (how-many empty)
0
```

Good!

Programming in 'off-the-shelf' languages

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Good!

```
> (how-many '(sigcse))
0
```

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The year is 1995, Rice @ Houston.
Scheme is my language *of hope*.

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0
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Wrong!

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Omitting parentheses produces a *syntactically correct* program with a *totally different meaning* than intended (begin).

Programming in ‘off-the-shelf’ languages

The year is Anytime, Anyplace @ Anywhere.
Your choice of the day is some professional language X for X in

- Basic
- Java
- JavaScript
- Python
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Problem: You will inevitably run into similar problems with syntax/error reporting.

Programming in ‘off-the-shelf’ languages

The year is Anytime, Anyplace @ Anywhere. Your choice of the day is some professional language X for X in

- **Basic**
- **Java**
- **JavaScript**
- **Python**
- **Ruby on Rails**

Problem: You will inevitably run into similar problems with syntax/error reporting.

Solution: You and your colleagues specify and use only a small portion of the language to keep your students safe.

Programming in a teaching language

The *Real* Problem: Your students don't stick to the chosen subset of the language.

Programming in a teaching language

The *Real* Problem: Your students don't stick to the chosen subset of the language.

Lesson 2a: If you specify and define a sublanguage, implement it and exploit the restrictions in the parser.

Programming in a teaching language

The parser of a professional language reports errors with messages that assume a *knowledgable programmer,* someone who knows *the* *whole* *language*.

Programming in a teaching language

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Programming in a teaching language

The parser of a professional language reports errors with messages that assume a *knowledgable programmer,* someone who knows *the whole language*.

Novices make mistakes, and by definition they don't know the whole language.

The parser of a *teaching* language reports errors with messages that assume a *knowledgable novice,* someone who knows *a small part of the language*.

Programming in a teaching language

```
int main() {
  double price_per_slice = 21.95 / 12;
  double total_due       = 0.0;
  int number_of_slices   = 0;

  cout << "how many slices did you eat?" << endl;
  cin >> number_of_slices;
  price_per_slice * number_of_slices  = total_due;
  cout << "your share is " << total_due << endl;
}
```

An assignment statement must have a variable on the left-hand side.

Programming in a teaching language

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}
```

An assignment statement must have a variable on the left-hand side.

The branch of a conditional must consist of one expression.

```
(define (how-many a-list)
  (cond
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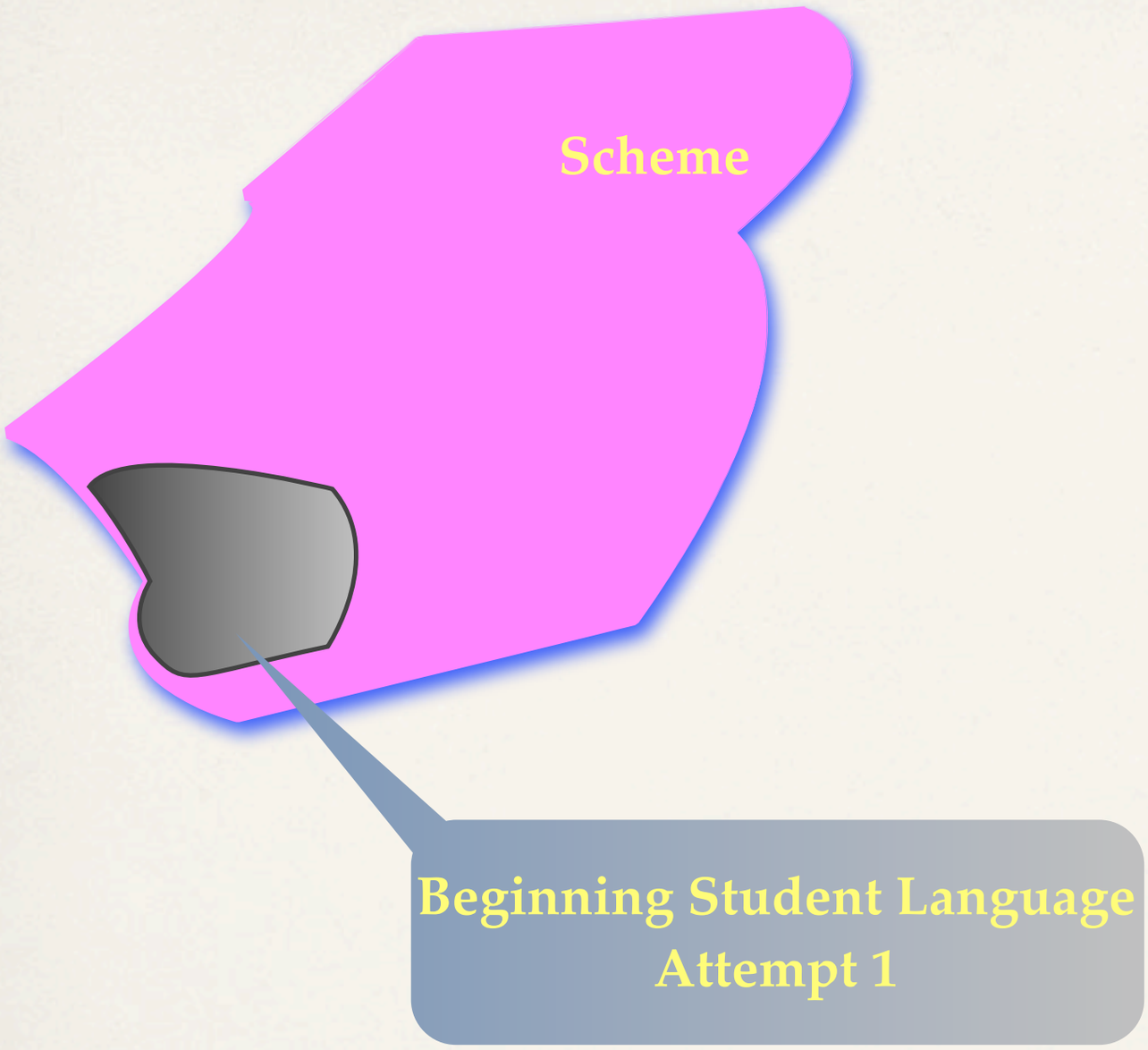
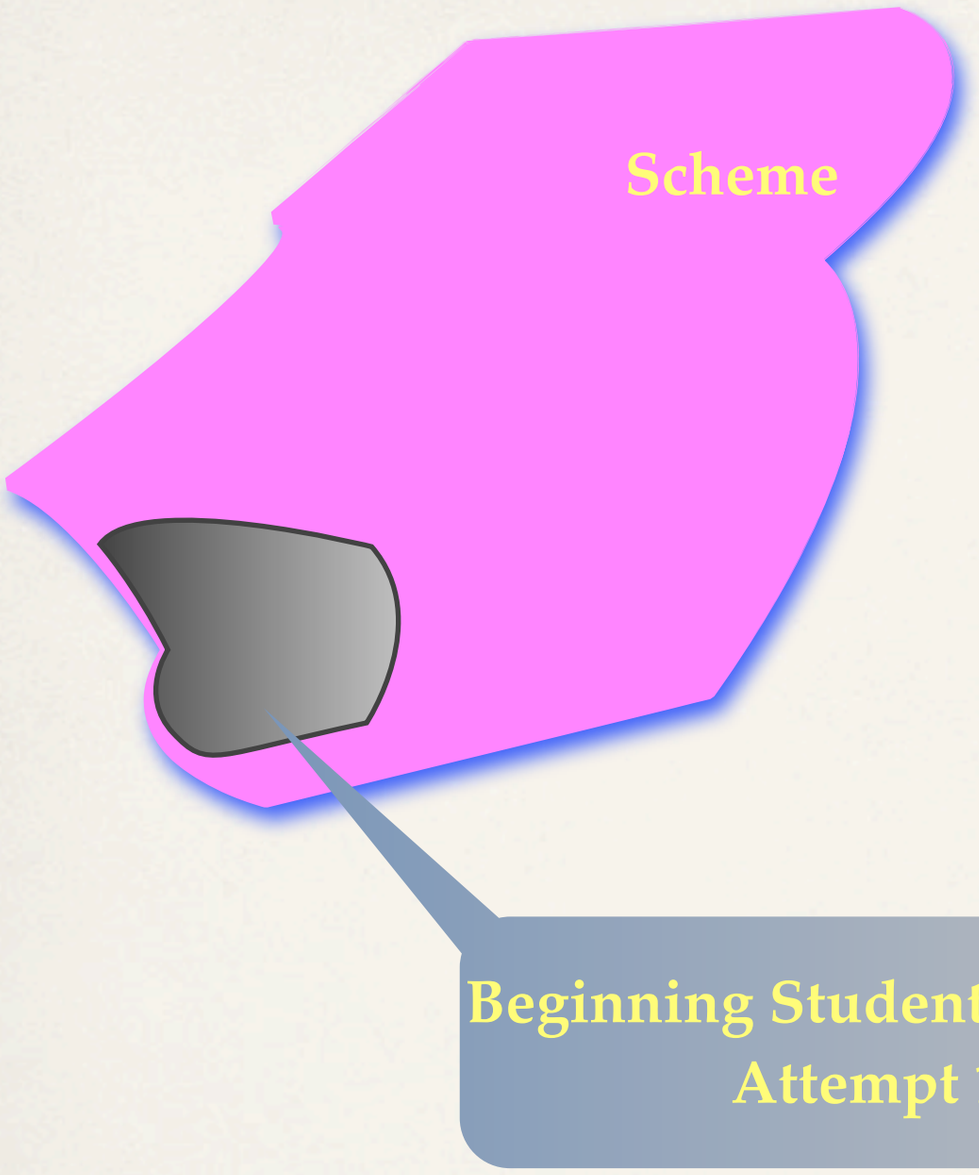
    [else add1 (how-many (rest a-list))]))
```

Programming in a teaching language

Programming in a teaching language

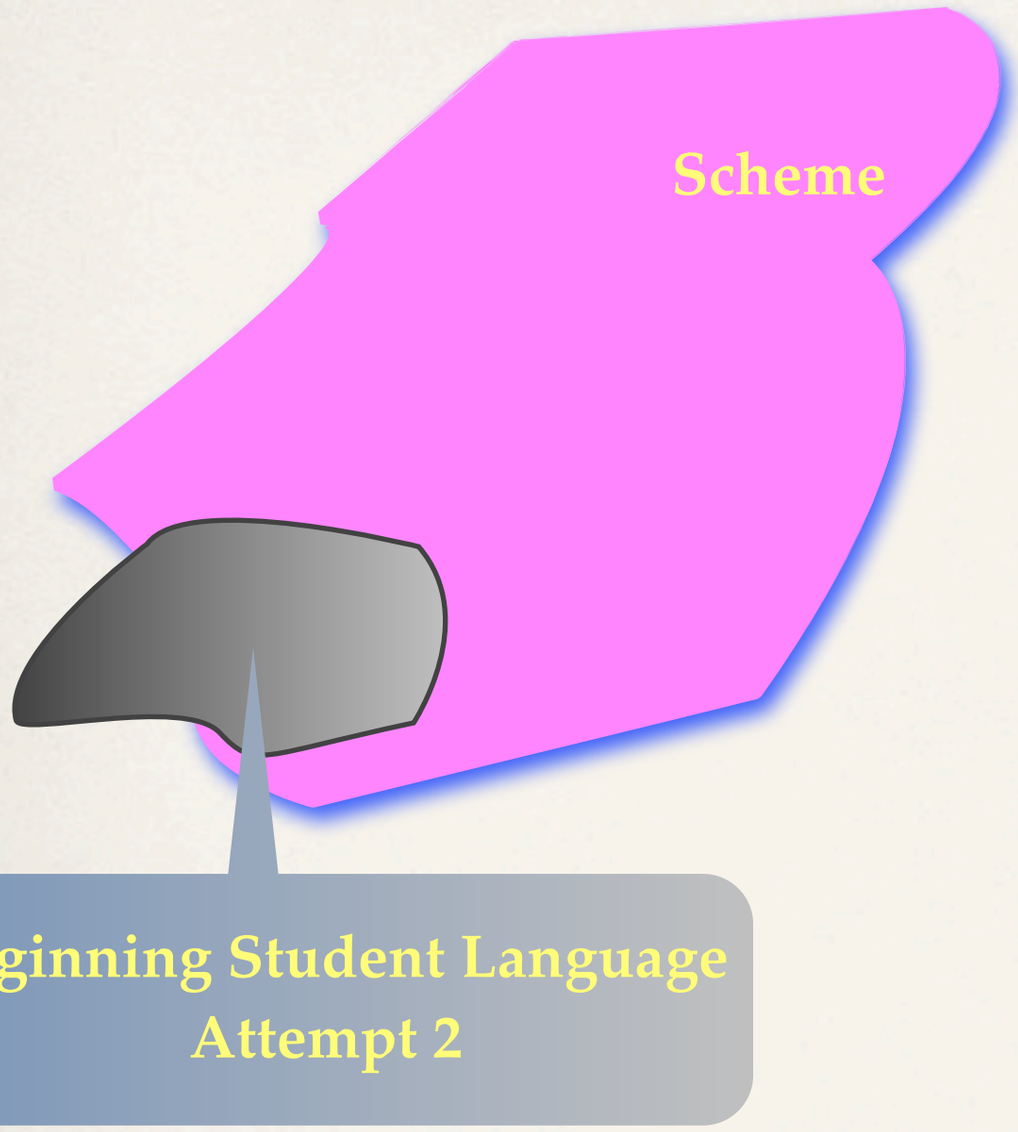


Programming in a teaching language



Lesson 2b: To teach *systematic design*, you may need a language that doesn't overlap with your chosen professional language.

Programming in a teaching language



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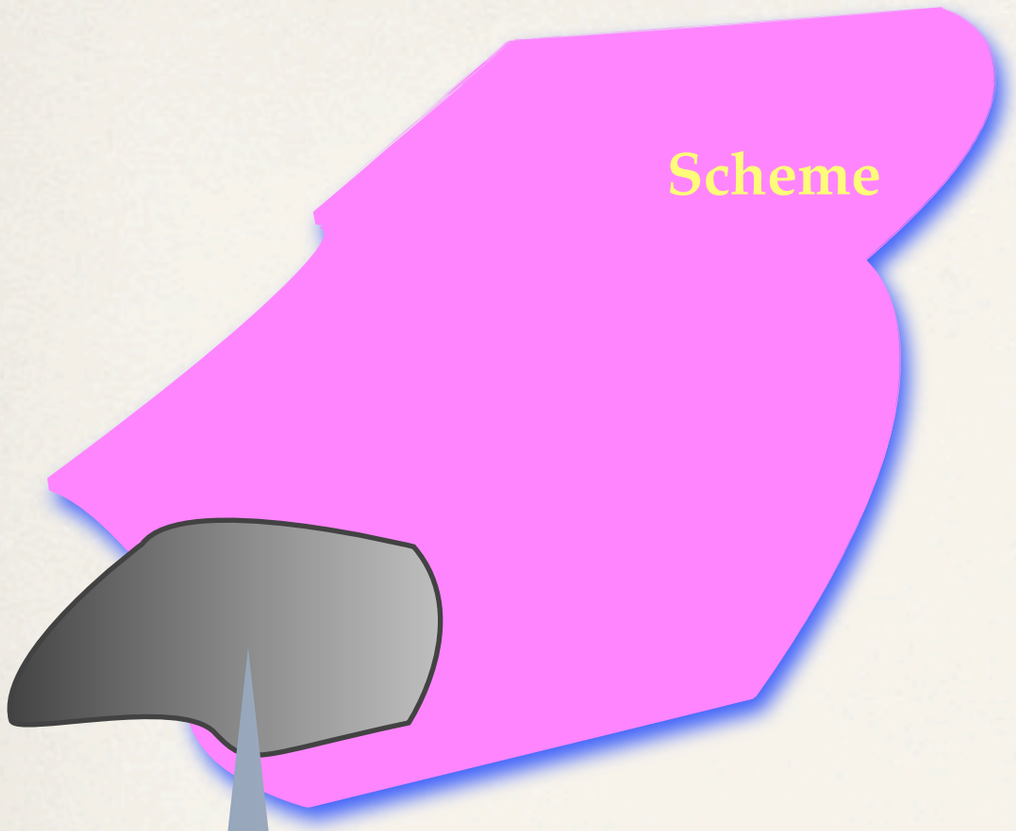


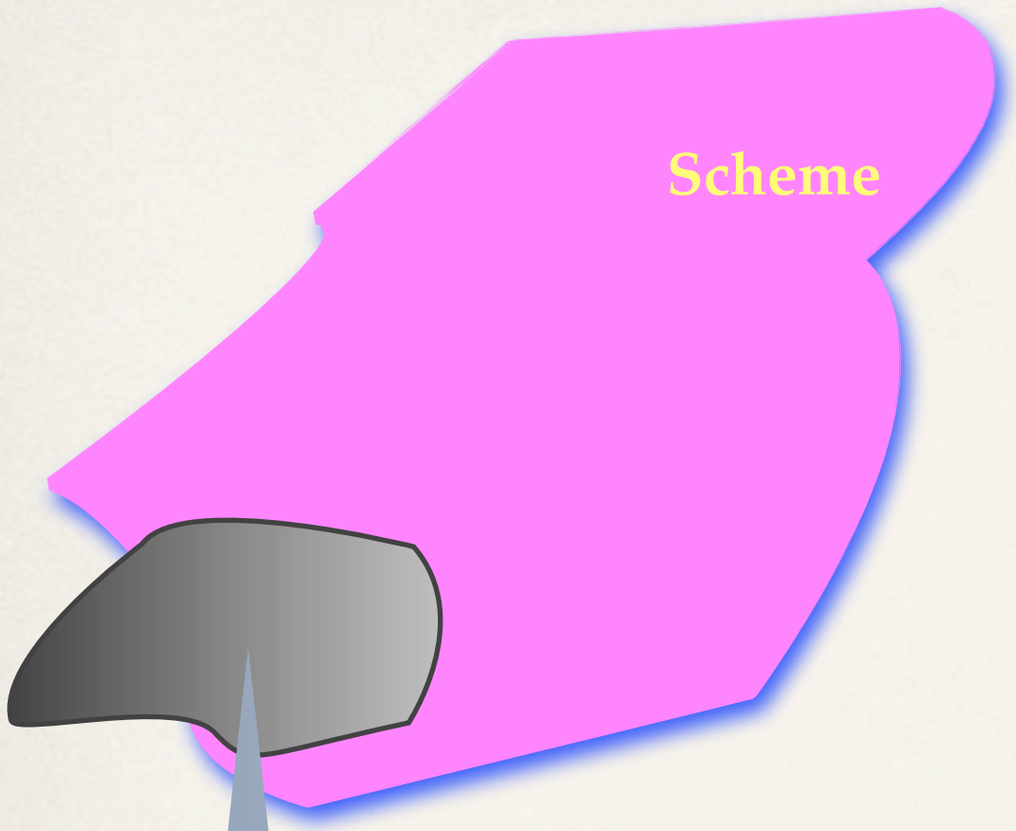
Lesson 2b: To teach *systematic design*, you may need a language that doesn't overlap with your chosen professional language.

Systematic Program **Design**

fun programming with "plain" **mathematics**

start with one and **smoothly** reach the other.

Programming in a teaching language



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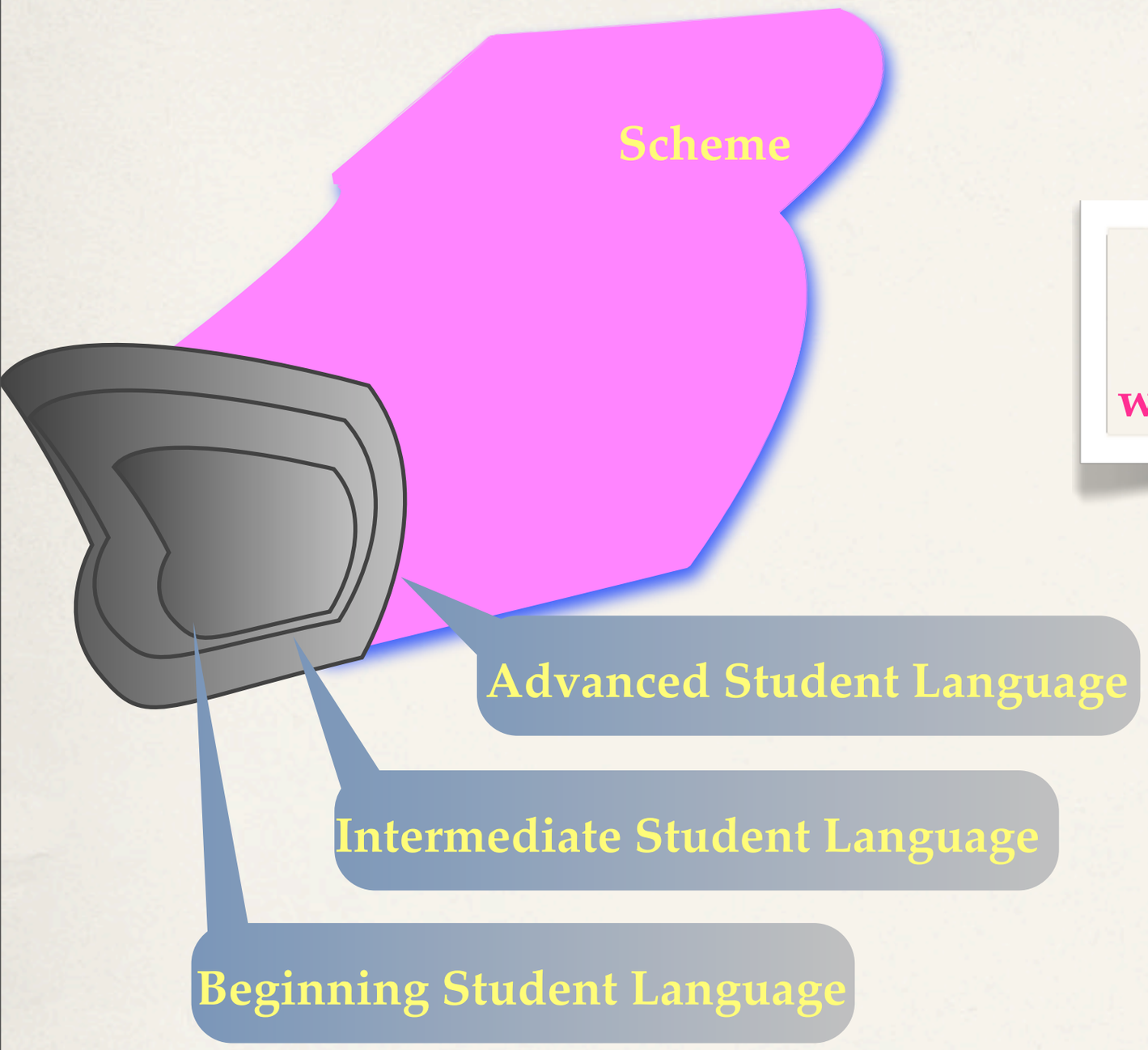

Lesson 2c: To accommodate smooth transitions, you need a whole *series of teaching languages*.

Programming in teaching languages: More Information

Felleisen, Findler, Flatt, Krishnamurthi.
The TeachScheme! project: computing and programming for every student.
Journal of Computer Science Education. Vol. **14**(1), **2004**, 55--77.

Findler, Flatt, Krishnamurthi, Steckler, Felleisen
The DrScheme Programming Environment.
Journal of Functional Programming. Vol. **12**(2), **2002**, 159--182.

Systematic Program Design

Programming by example

Problem: Design a program that determines whether a mouse click is inside some given shape. A shape is one of the following:

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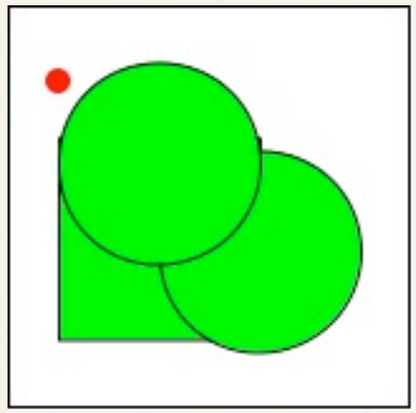

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(DARPA Programming Contest, 1993)

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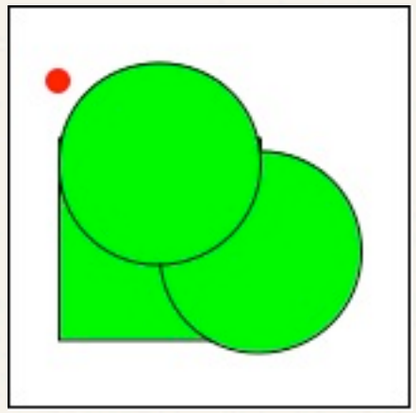

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Is a Cartesian point inside some shape?

Programming by example

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

;; Shape Point -> Boolean
;; is point pt inside of shape sh?
(define (shape-in? sh pt)
  (cond
    [(is-square? sh) (square-in? sh pt)]
    [(is-circle? sh) (circle-in? sh pt)]
    [(is-composition? sh)
       (or (shape-in? (shape-top sh) pt)
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```

Programming by example

```
interface IShape {
  // is point pt inside of this shape
  boolean inside(Point pt);
}

class Square implements IShape {
  private Point location;
  private int size;
  public boolean inside(Point pt) { ... }
}

class Circle implements IShape {
  private Point location;
  private int radius;
  public boolean inside(Point pt) { ... }
}

class Composition implements IShape {
  private IShape top;
  private IShape bot;
  public boolean inside(Point pt) {
    return top.inside(pt) || bot.inside(pt);
  }
}
```

Programming by example

Problem Statement

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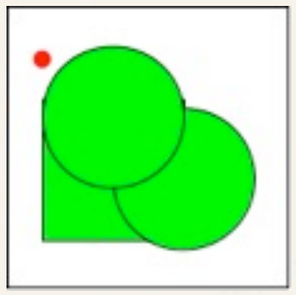

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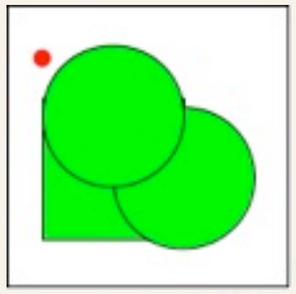

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How did you go from the *problem statement* to the *solution?*

Programming by example

How do you teach your students to get from here to there?

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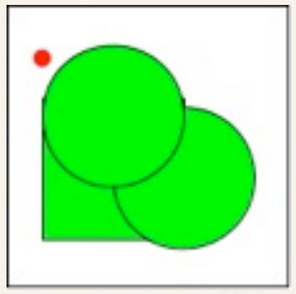

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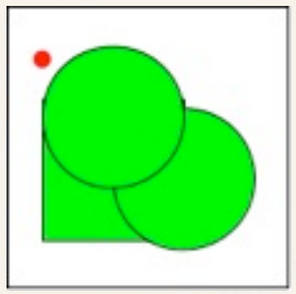

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```

What do you do when your students get stuck?

How did you go from the *problem statement* to the *solution?*

Lesson 3: To empower your students, you need a systematic design process from the *very* beginning.

How to Design Programs

Structural Design: Forms of Data

The Design Recipe

	atomic	enumer.	structs	hier.	union	recursive	mut. rec.
data description							
purpose statement							
functional examples							
template | outline							
code!							
examples to testing							

Process Steps

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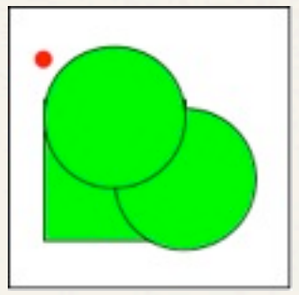

How to Design Programs -- *data descriptions*

Q: What kind of information does the problem talk about?

A: *Points* and *Shapes*, incl. *Squares, Circles, & Composits*

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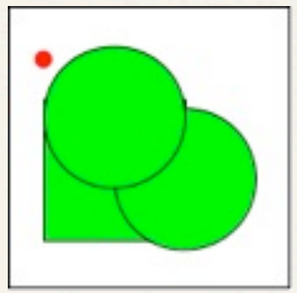

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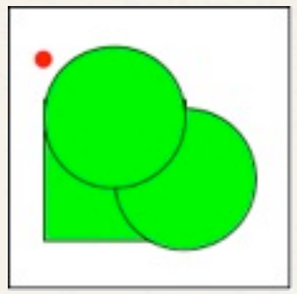

Q: What data do you use to represent this information?

A: Structures & unions.

```
(struct point (x y))

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(struct circle (location radius))
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;; A Shape is a square, a circle,
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```

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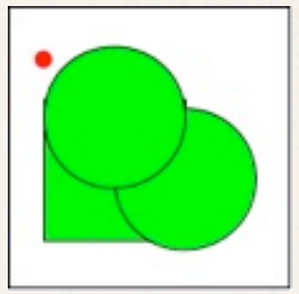

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```

Q: Can you create example instances from your data descriptions?

A: If not, they are not precise enough.

```
(define ex1 (square (point 10 20) 50))
(define ex2 (circle (point 30 10) 40))
(define ex3 (composition ex1 ex2))
```

How to Design Programs -- *signature & purpose statement*

Q: What kind of data does the desired method/function consume? What does it produce?

A: It consumes *Points* and *Shapes* & returns *Boolean*.

Problem Statement

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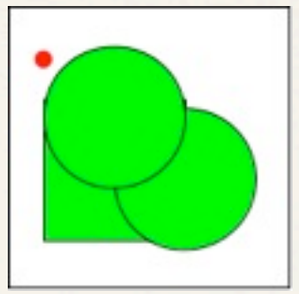

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```

How to Design Programs -- *signature & purpose statement*

Q: What kind of data does the desired method/function consume? What does it produce?

A: It consumes *Points* and *Shapes* & returns *Boolean*.

Q: Can you summarize its purpose as a one-liner?

A: It checks whether the given *Point* is inside the given *Shapes* & returns *Boolean*.

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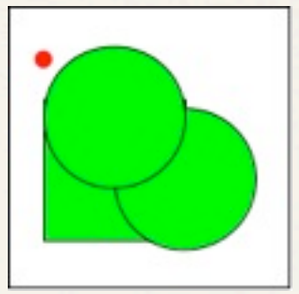

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```
;; is point pt inside of shape sh?
```

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A: It checks whether the given *Point* is inside the given *Shapes* & returns *Boolean*.

Q: Can you formulate a function stub?

A: The function takes two arguments and *false* is a good sample value.

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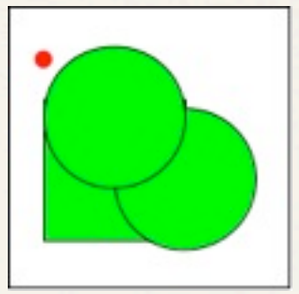

```
;; Shape Point -> Boolean
```

```
;; is point pt inside of shape sh?
```

```
(define (in? sh pt)
  false)
```

How to Design Programs -- *functional examples*

Q: Can you illustrate the purpose statement with examples?

A: It is good to start from the data examples.

Problem Statement

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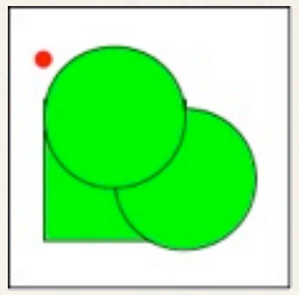


```
;; given (square (point 10 20) 30) and (point 15 25)
;; the answer should be true
;; given (circle (point 20 30) 10) and (point 90 90)
;; the answer should be false
```

How to Design Programs -- *functional examples*

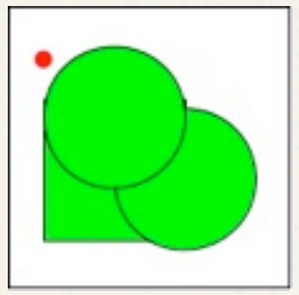
Q: Can you illustrate the purpose statement with examples?

A: It is good to start from the data examples.

Problem Statement

Problem: Design a program that determines whether a mouse click is inside some given shape. A shape is one of the following:

-- a square of some size at some location;
-- a circle of some radius at some location;
-- or the composition of two shapes,
one shape on top of another.



```
;; given (square (point 10 20) 30) and (point 15 25)
;; the answer should be true
;; given (circle (point 20 30) 10) and (point 90 90)
;; the answer should be false
```

Q: Can you formulate them as test cases?

```
(check-expect (in? ex1 pt0) true)
(check-expect (in? ex2 pt0) false)
(check-expect (in? ex3 pt0) true) ;; or (!)
```

How to Design Programs -- *functional examples*

Q: Can you illustrate the purpose statement with examples?

A: It is good to start from the data examples.

Problem Statement

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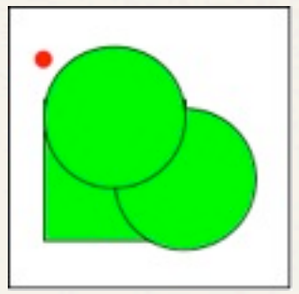

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```

Q: Can you formulate them as test cases?

Lesson 2d: Your PL must support *test coverage* automatically.

```
(check-expect (in? ex1 pt0) true)
(check-expect (in? ex2 pt0) false)
(check-expect (in? ex3 pt0) true) ;; or (!)
```

How to Design Programs -- *time for an outline*

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex3 (composition ex1 ex2))

;; A Shape is one of:
;; -- (square Point NaturalNumber)
;; -- (circle Point NaturalNumber)
;; -- (composition Shape Shape)

;; Shape Point -> Boolean
;; is point pt inside of shape sh?

(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  false)
```

How to Design Programs -- *time for an outline*

The goal of this step is to systematically create the body of the function from the data definition.

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex3 (composition ex1 ex2))

;; A Shape is one of:
;; -- (square Point NaturalNumber)
;; -- (circle Point NaturalNumber)
;; -- (composition Shape Shape)

;; Shape Point -> Boolean
;; is point pt inside of shape sh?

(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  false)
```

How to Design Programs -- *time for an outline*

Q: How many subclasses does the data definition mention?

A: Three. And therefore we need a 3-way conditional.

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex3 (composition ex1 ex2))

;; A Shape is one of:
;; -- (square Point NaturalNumber)
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;; -- (composition Shape Shape)

;; Shape Point -> Boolean
;; is point pt inside of shape sh?

(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  (cond
    [...   ...]
    [...   ...]
    [...   ...]))
```

How to Design Programs -- *time for an outline*

Q: Which predicates distinguish the subclasses?

A: *square*? and *circle*? and *composition*? of *sh*

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex3 (composition ex1 ex2))

;; A Shape is one of:
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;; is point pt inside of shape sh?

(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  (cond
    [(square? sh) ...]
    [(circle? sh) ...]
    [(composition? sh) ...]))
```

Q: Which cases deal with structures?

A: All and the outline should list their fields.

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex3 (composition ex1 ex2))

;; A Shape is one of:
;; -- (square Point NaturalNumber)
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(define (in? sh pt)
  (cond
    [(square? sh) ... sh ...]
    [(circle? sh) ... sh ...]
    [(composition? sh)
     ...(composition-top sh)...
     ...(composition-bot sh)...]))
```

Q: Do any of the fields refer back to the data definition?

A: The two in the third case, and that is where *in?* needs recursion.

```
(struct square (location size))
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(define ex3 (composition ex1 ex2))

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    [(composition? sh)
     ..(in? (composition-top sh))...
     ..(in? (composition-bot sh)).]))
```

How to Design Programs -- *code!*

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex1 (square (point 10 20) 50))
(define ex2 (circle (point 30 10) 40))
(define ex3 (composition ex1 ex2))
```

Q: Can you infer from the examples the return value for the base cases?

A: ... left to auxiliaries ...

```
;; Shape Point -> Boolean

(check-expect (in? ex2 pt0) false)
(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  (cond
    [(square? sh) ... sh ...]
    [(circle? sh) ... sh ...]
    [(composition? sh)
     ..(in? (composition-top sh)) ...
     ..(in? (composition-bot sh)).]))
```

How to Design Programs -- *code!*

```
(struct square (location size))
(struct circle (location radius))
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(define ex1 (square (point 10 20) 50))
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```
;; Shape Point -> Boolean

(check-expect (in? ex2 pt0) false)
(check-expect (in? ex3 pt0) true)

(define (in? sh pt)
  (cond
    [(square? sh) (in-square? sh pt)]
    [(circle? sh) (in-circle? sh pt)]
    [(composition? sh)
     ..(in? (composition-top sh))...
     ..(in? (composition-bot sh)).]))
```

Q: Can you infer from the examples how to combine the values of the expressions in the *recursive* case(s)?

A: Yes a point is in a composite shape if it is either in one or the other.

How to Design Programs -- *code!*

```
(struct square (location size))
(struct circle (location radius))
(struct composition (top bot))

(define ex1 (square (point 10 20) 50))
(define ex2 (circle (point 30 10) 40))
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```
;; Shape Point -> Boolean

(check-expect (in? ex2 pt0) false)
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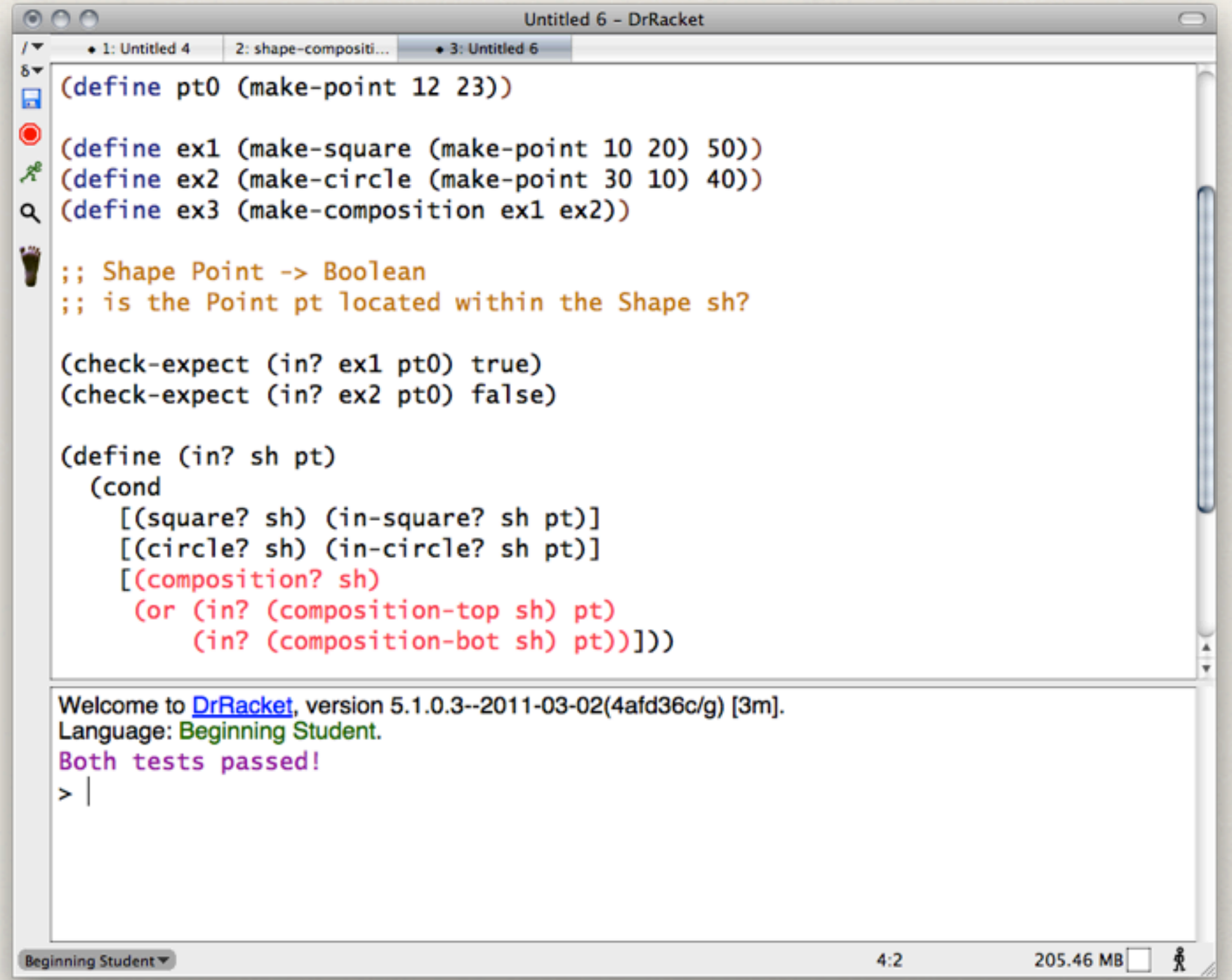
(define (in? sh pt)
  (cond
    [(square? sh) (in-square? sh pt)]
    [(circle? sh) (in-circle? sh pt)]
    [(composition? sh)
     (or(in? (composition-top sh pt))
        (in? (composition-bot sh pt)))]))
```

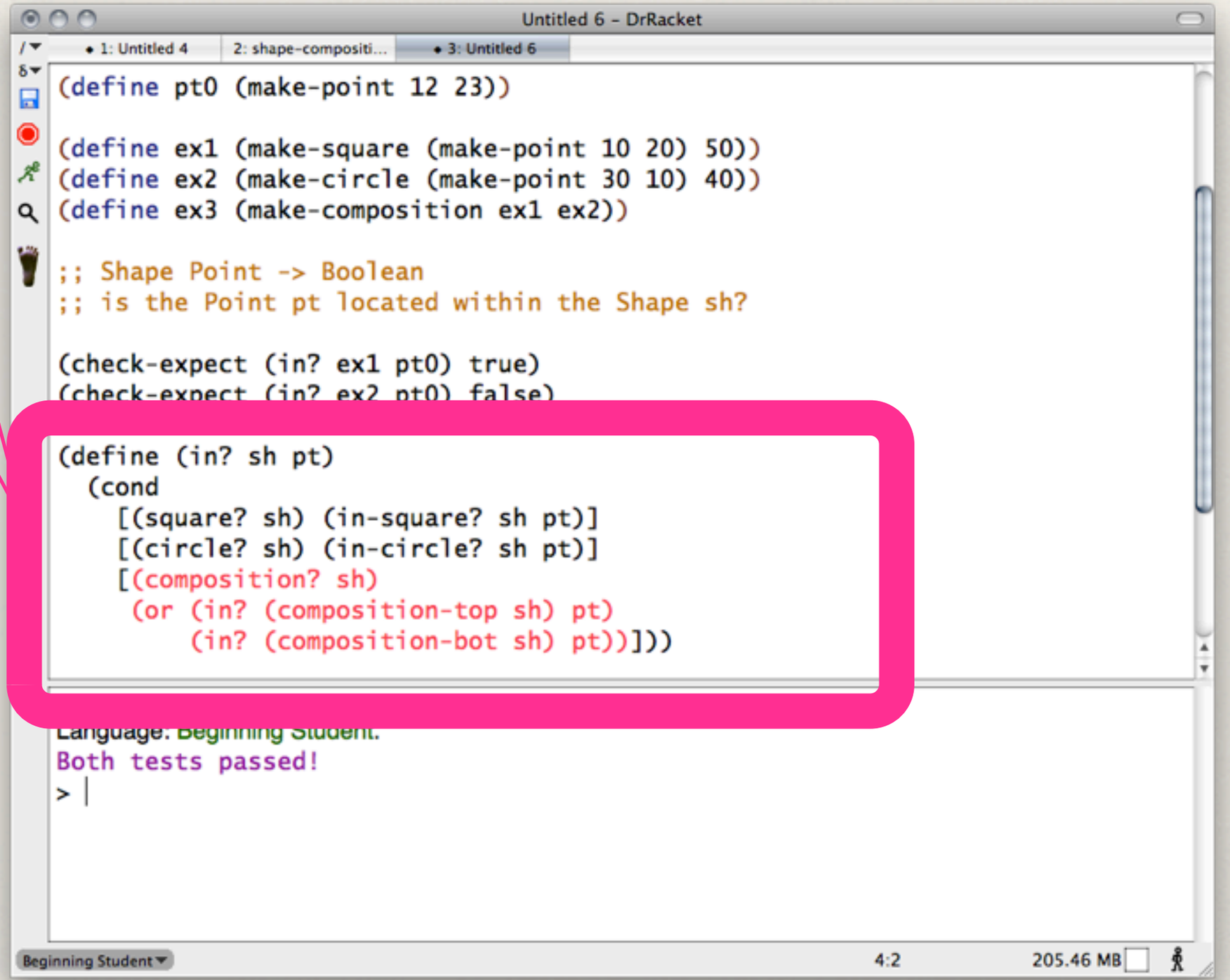
How to Design Programs -- *test and explore coverage*



How to Design Programs -- *test and explore coverage*

Q: Can you run your tests and check the coverage?

A: Red is like a bug.



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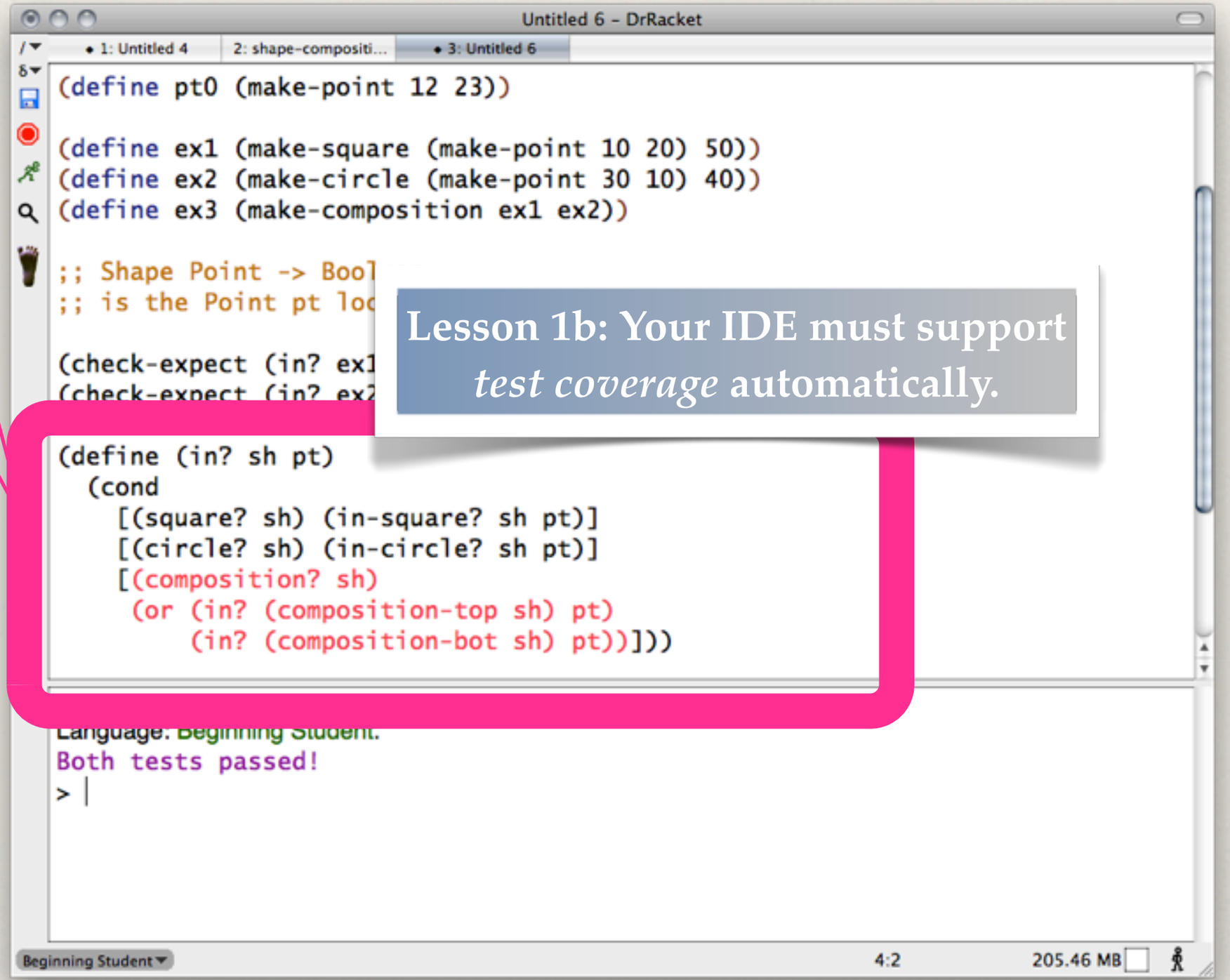

Lesson 1b: Your IDE must support *test coverage* automatically.

How to Design Programs

Structural Design: Forms of Data

The Design Recipe

Process Steps

	atomic	enumer.	structs	hier.	union	recursive	mut. rec.
data description							
purpose statement							
functional examples							
template | outline							
code!							
examples to testing							

How to Design Programs

Structural Design: Forms of Data

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None of the questions referred to the problem.

How to Design Programs

Structural Design: Forms of Data

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Process Steps	functional examples						
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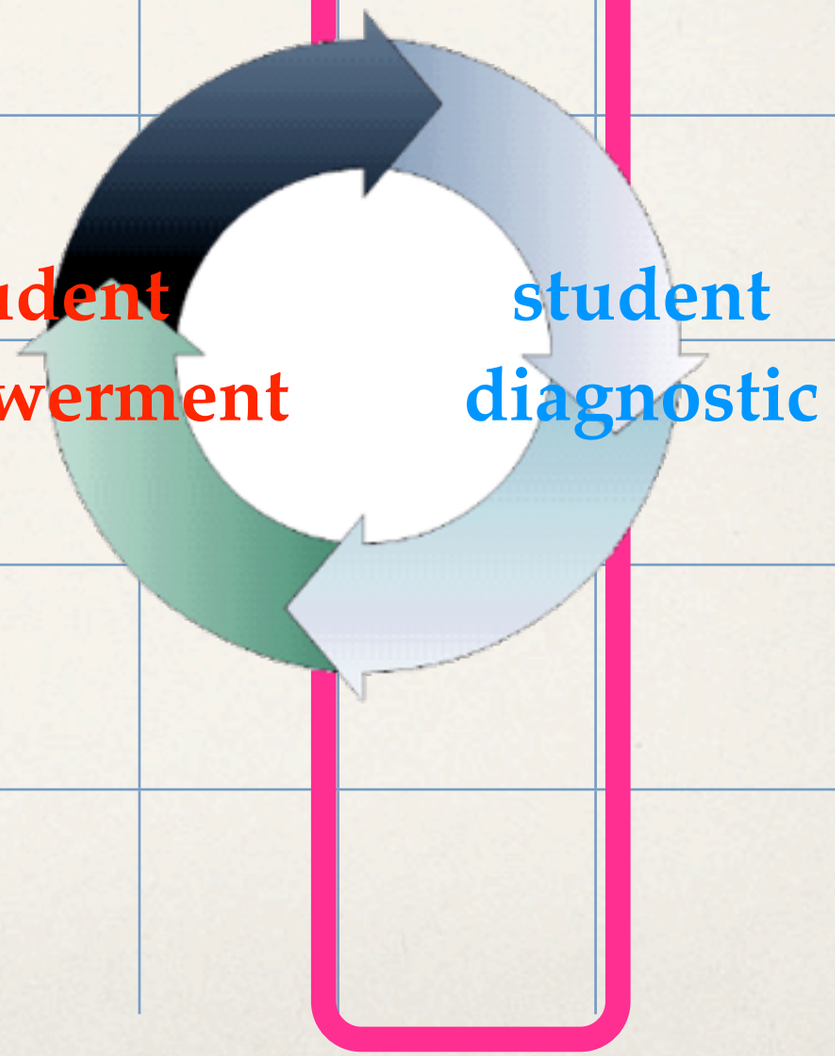
None of the questions referred to the problem.

This is *good*:
-- it helps you diagnose students' problems
-- it empowers your student eventually



How to Design Programs

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	atomic	enumer	structs	hier	union	recursive	mut. rec.
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Process Steps

There is lots more on design:

-- structural design

-- abstracting design

-- generative recursion

-- design with mutation

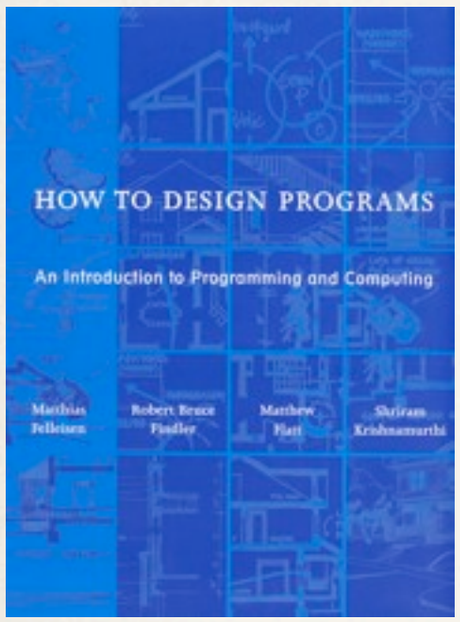
-- iterative refinement

-- designing GUIs

-- designing batch

How to Design Programs: the book

two text books in one



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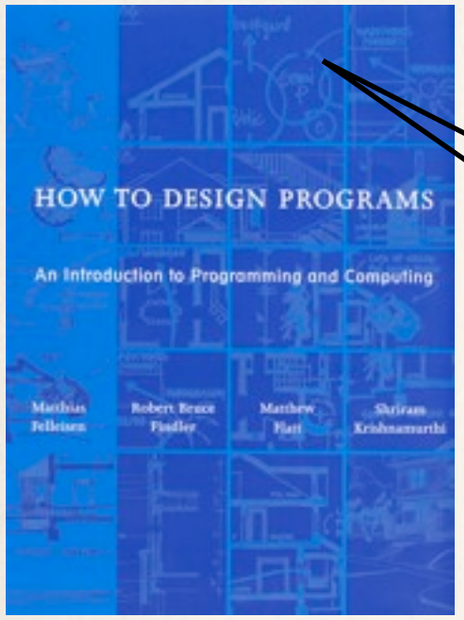

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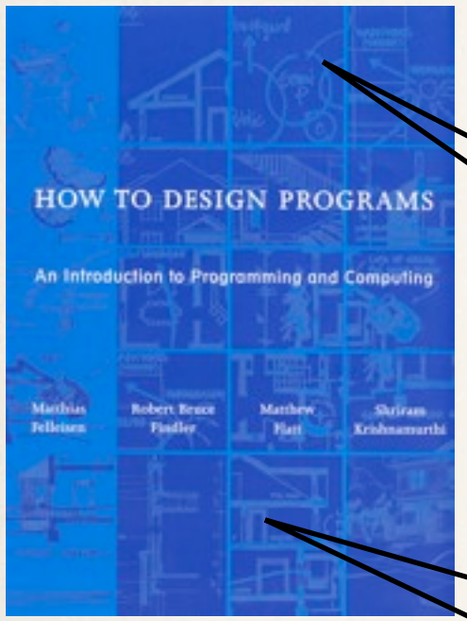

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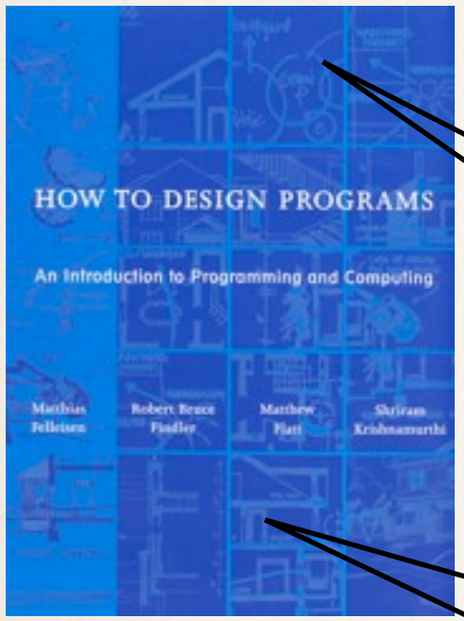

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http://www.htdp.org/ [edition 1]

http://www.ccs.neu.edu/home/matthias [edition 2]

Failures & Challenges

Error Message: How well did we do?

Untitled 8 – DrRacket

1: Untitled 4 | 2: shape-compositi... | 3: Untitled 6 | 4: Untitled 8

```
;; -------------------------------
;; Number -> {-1,0,+1}
(define (sign.v1 x)
  (cond
    [(positive? x) +1]
    [(zero? x)      0]
    [(negative? x) -1]))

;; -------------------------------
;; Number -> {-1,0,+1}
(define (sign.v2 x)
  (cond
    (positive? x) +1
    [(zero? x)      0]
    [(negative? x) -1]))
```

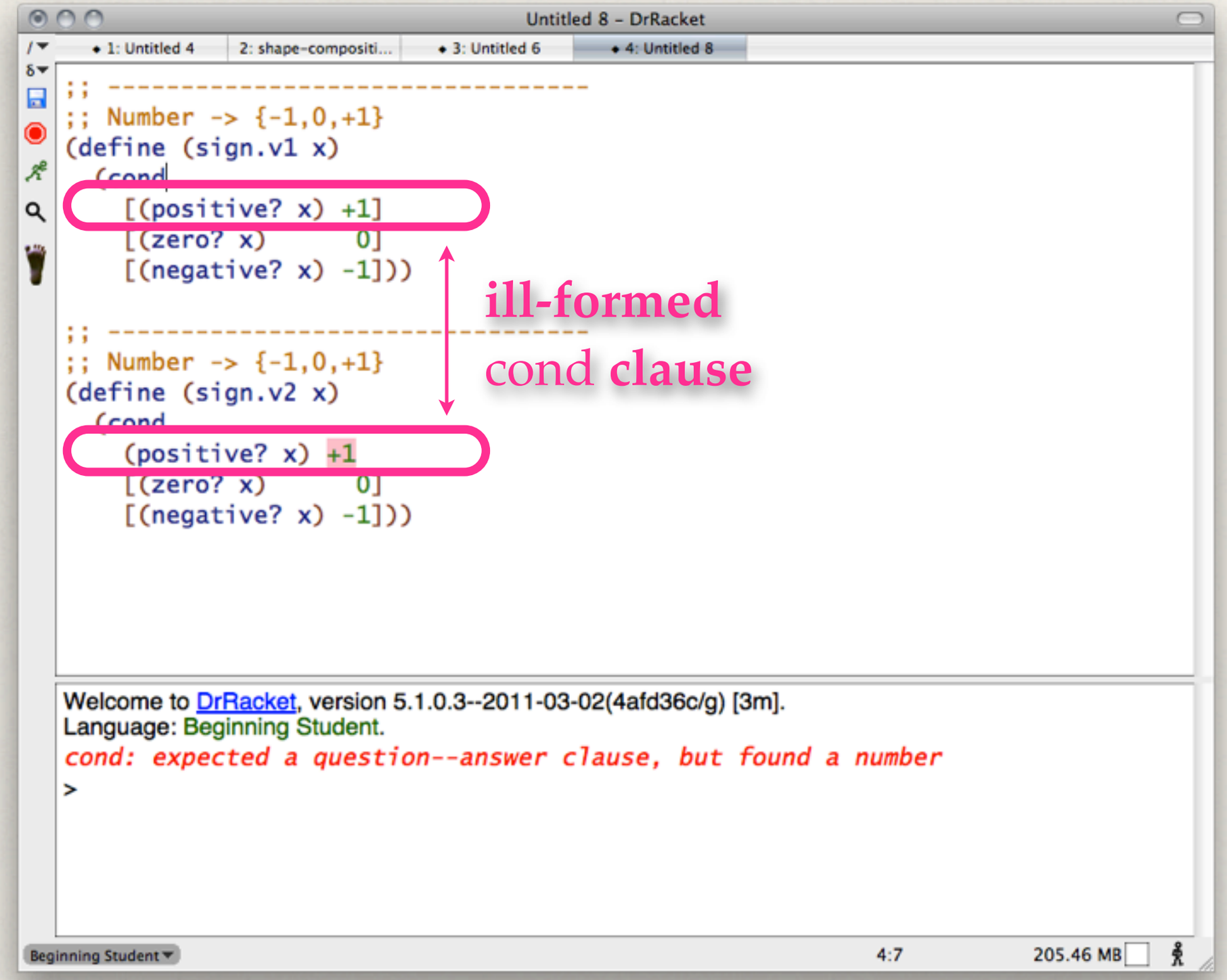
Welcome to DrRacket, version 5.1.0.3--2011-03-02(4afd36c/g) [3m].
Language: Beginning Student.

cond: expected a question--answer clause, but found a number

>

Beginning Student | 4:7 | 205.46 MB

Error Message: How well did we do?



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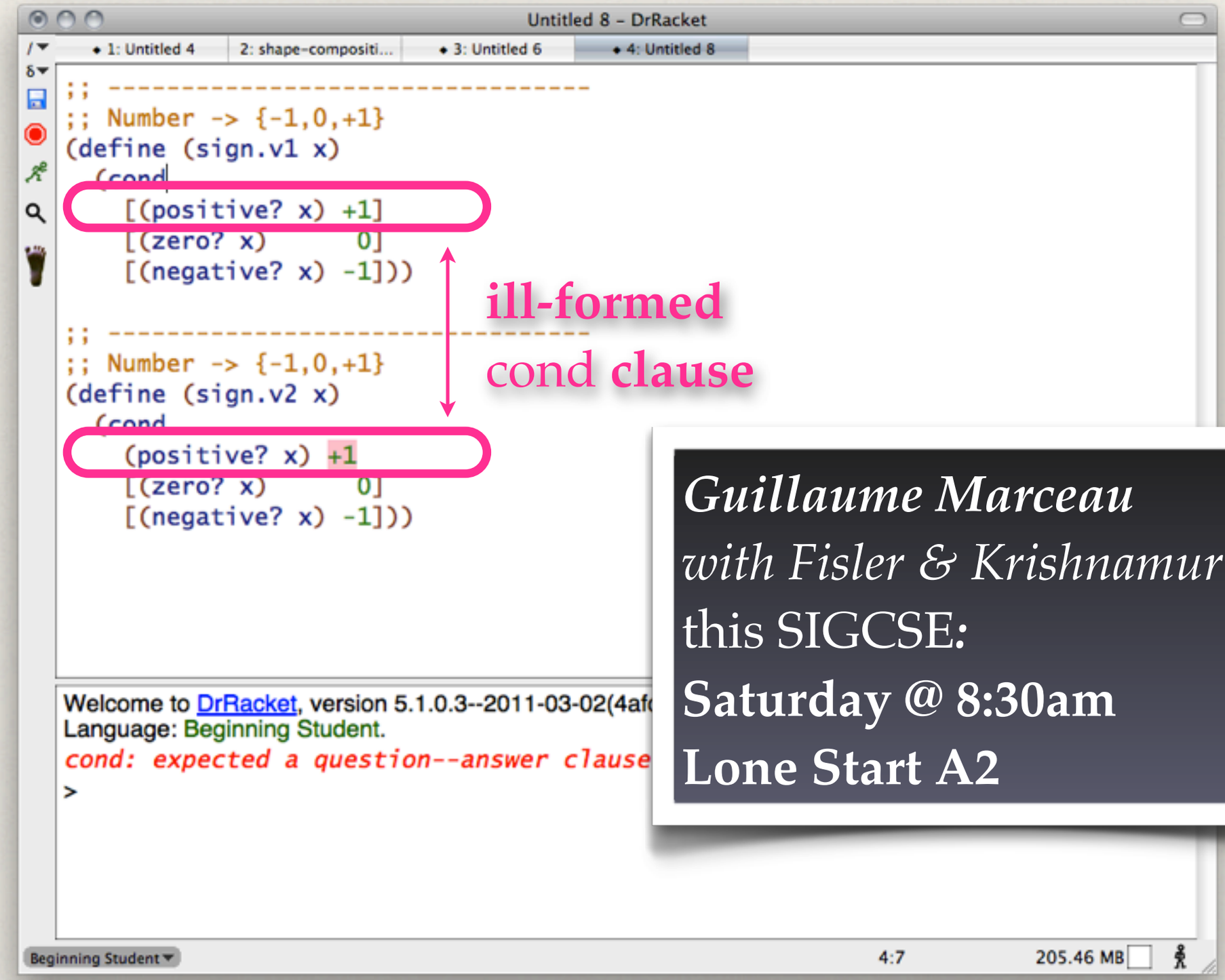
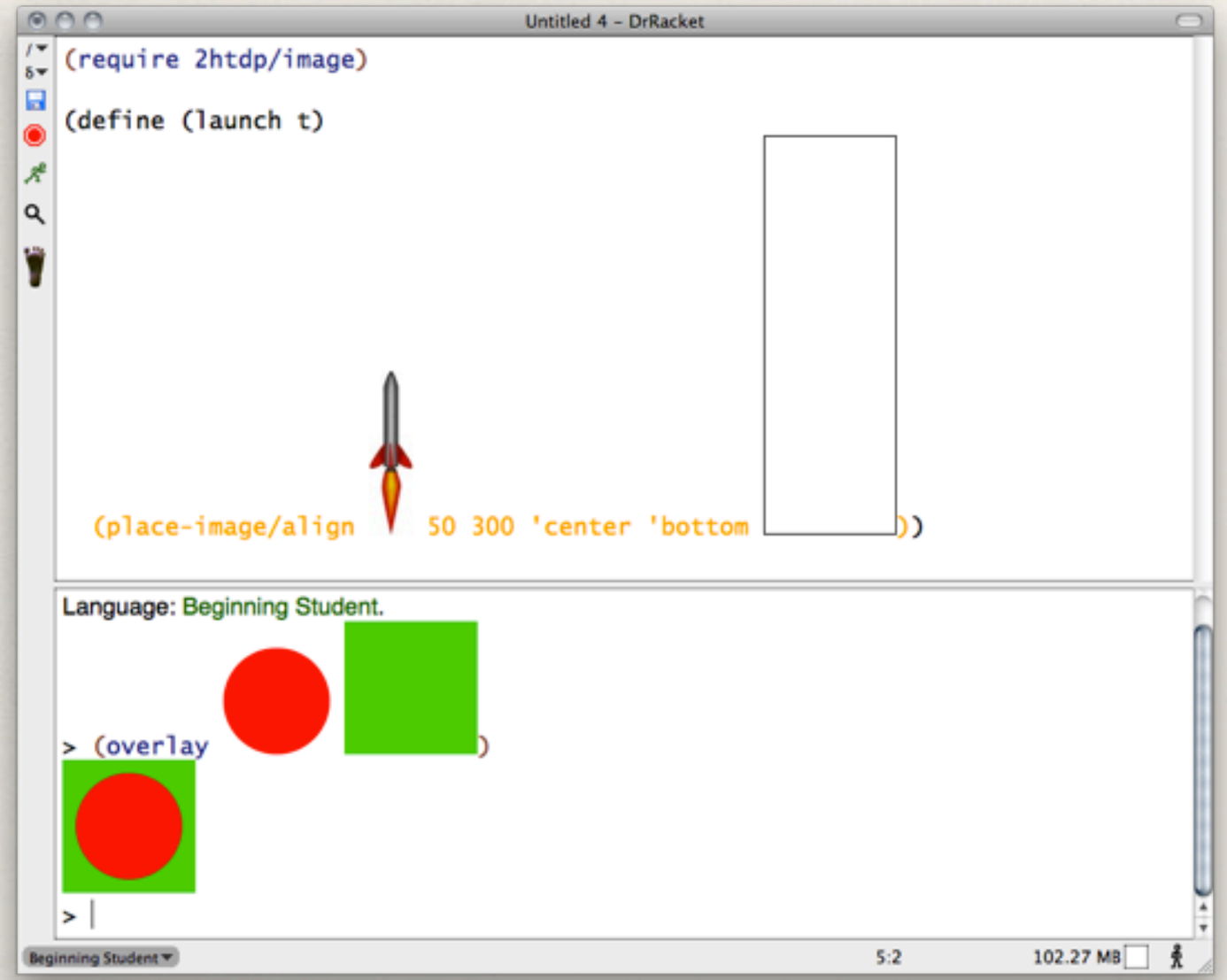


Guillaume Marceau
with Fisler & Krishnamurthi
this SIGCSE:
Saturday @ 8:30am
Lone Start A2

Delivery: Desk Top vs Web Browser



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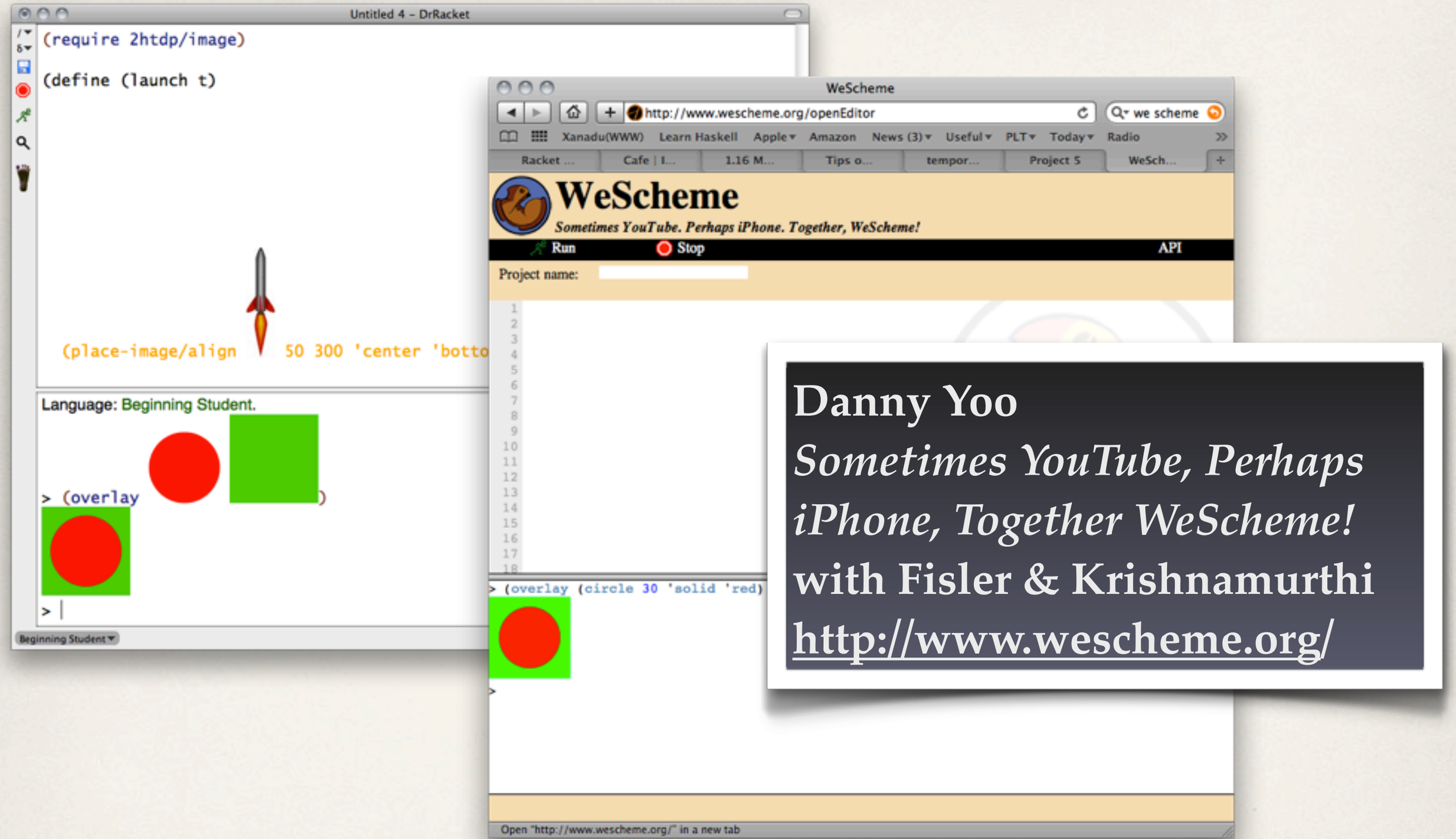

Danny Yoo

Sometimes YouTube, Perhaps iPhone, Together WeScheme!

with Fisler & Krishnamurthi

http://www.wescheme.org/

Syntax (1): How about those parentheses?

Valid Scheme

```
(moo-baz
  (* (foo bar)
     (add1 g))
  (retrieve
    qux
    (-> zip ding)))
```

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(moo-baz
  (* (foo bar)
     (add1 g))
  (retrieve
    qux
    (-> zip ding)))
```

Valid C++

```
((foo<bar>)*(g++))
.baz(!&qux::zip->ding());
```

Can you determine in which order the pieces are evaluated?

Syntax (2): Is editing a pain?

```
;; RealNumber -> {+1,0,-1}
(define (sign x)
  (cond
    [(positive? x) +1]
    [(zero? x)      0]
    [(negative? x) -1]))
```

Editing *any syntax* is a painful exercises for all middle school kids and other people too.

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Editing *any syntax* is a painful exercises for all middle school kids and other people too.

We should have added some structure-oriented editing a long time ago.

Syntax *vs.* mathematics

What do all these pieces of C/C++/ Java/et alii have in common?

```
x = x + 1
```

```
for(i = 0; i < 10, i++) {
  sum = sum + i;
```

```
while (!in.eof) {
  next = readInt();
  sum = sum + next;
}
```

Syntax *vs.* mathematics

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None of this is mathematics. Worse, some of it looks like mathematics but has nothing to do with it.

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while (!im.eof) {
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```

C++/Java/Python/[smother mathematics.]/friends

None of this is mathematics. Worse, some of it looks like mathematics but has nothing to do with it.

Syntax *vs.* mathematics

What do all these fragments from our teaching languages have in common?

```
(define x 10)
```

```
(define (conversion f)
  (* 9/5 (- f 32)))
```

```
(define (edit editor ke)
 (if (control-key? ke)
     editor
     (juxtapose editor ke)))
```

Syntax *vs.* mathematics

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(define x 10)
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```
(define (conversion f)
  (* 9/5 (- f 32)))
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```
(define (edit editor ke)
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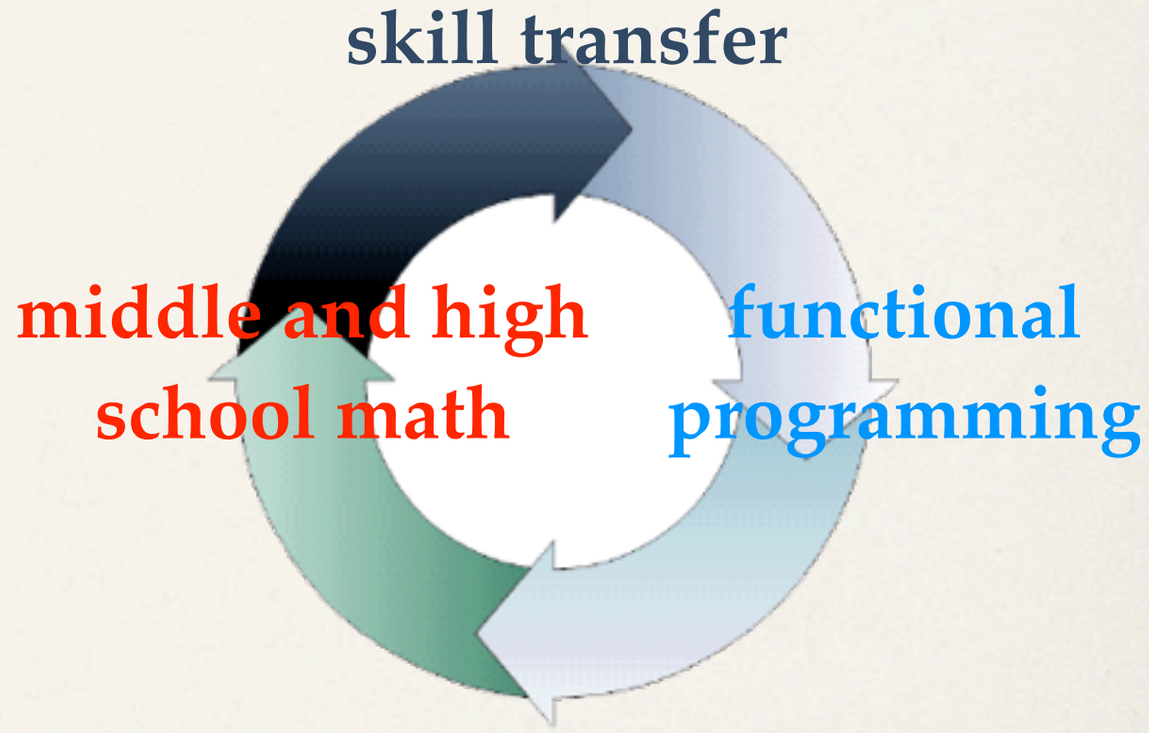
```

None of this may *look like* mathematics from middle school texts but every construct has a direct and easily recognizable counterpart in mathematics.

Syntax (3): Its meaning really *is* mathematics

So you may not like the parentheses, but the teaching languages really are mathematics.



Scheme, it's all about Scheme

All computer science curricula start from a course on the *currently fashionable* programming language.

Scheme, it's all about Scheme

Every first course must be
about *a programming language.*
Ergo, yours must be about Scheme.

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Scheme, it's all about Scheme

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All computer science curricula start from a course on the *currently fashionable programming language.*

No, it really is about connecting mathematics and programming and design.

The *Program by Design* Project

Matthias Felleisen (PLT)
Northeastern University

Two Conclusions

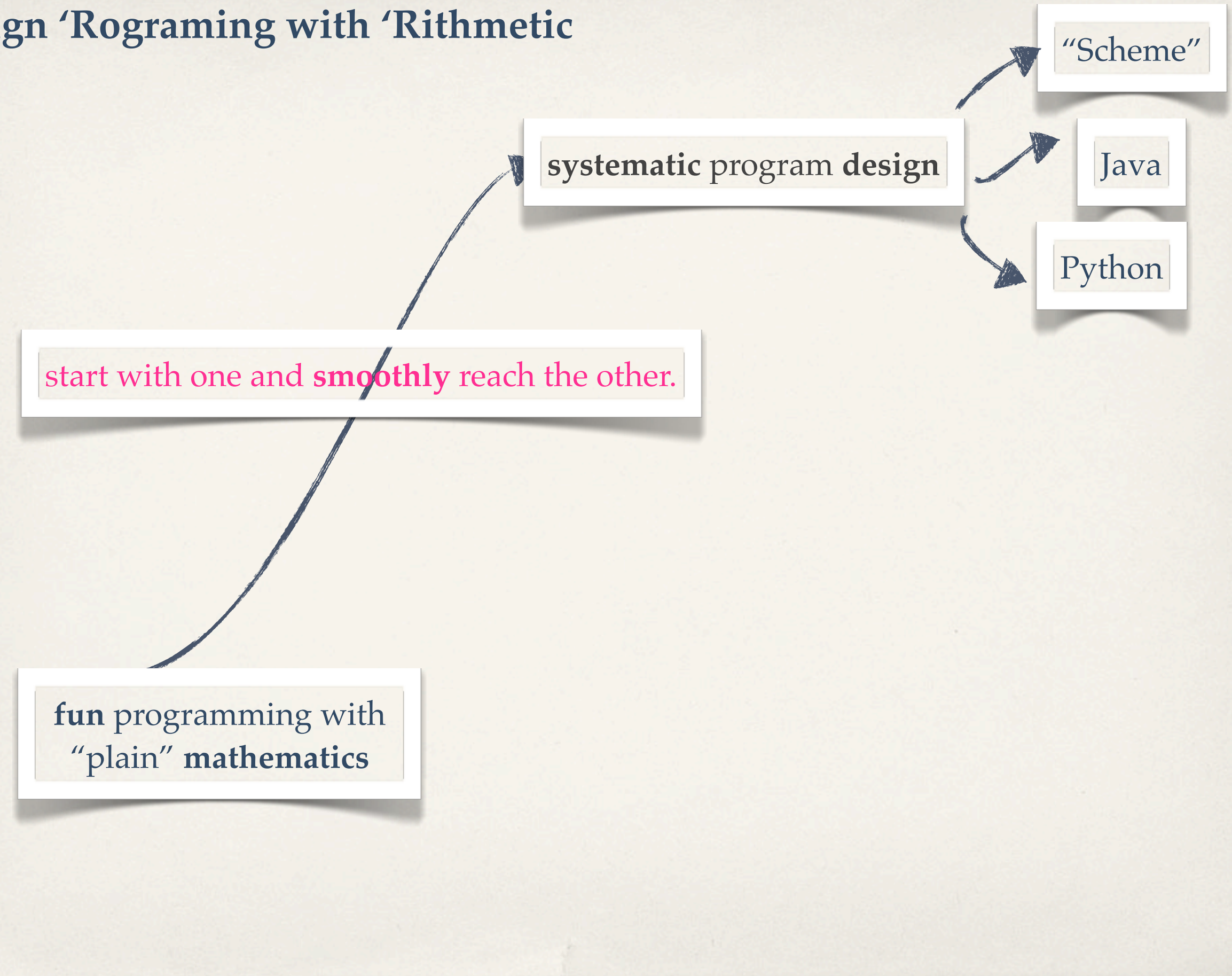
The *Program by Design* Idea: Align 'Rograming with 'Rithmetic

systematic program **design**

start with one and **smoothly** reach the other.

fun programming with "plain" **mathematics**

The *Program by Design* Idea: Align 'Rograming with 'Rithmetic



The *Program by Design* Idea: Align 'Rograming with 'Rithmetic

Softw. Eng.

"Scheme"

systematic program **design**

Java

Python

start with one and **smoothly** reach the other.

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The *Program by Design* Idea: Align 'Rograming with 'Rithmetic

Softw. Eng.

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systematic program **design**

Java

Python

start with one and **smoothly** reach the other.

transition to logic:
ACL2 & proving theorems
about video games

fun programming with
"plain" **mathematics**

General Lessons

Lesson 1: Your PL/IDE must support *an* arithmetic of images.

Get'em hooked. Programming with mathematics is fun and benefits all.

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Implemented teaching languages ease kids into programming.

General Lessons

Lesson 1: Your PL/IDE must support *an* arithmetic of images.

Get'em hooked. Programming with mathematics is fun and benefits all.

Lesson 2: If you specify and define a sublanguage, implement it and exploit the restrictions in the parser. And you need more than one.

Implemented teaching languages ease kids into programming.

Lesson 3: To help your students solve computational design problems, you need a systematic design process from the *very* beginning.

It helps you diagnose your students' prolems and it empowers them so that they can solve problems on their own.

The End

with thanks to Shriram, Matthew, Robby, Kathi, and

The End

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Dan Anderson
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Jack Clay
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Marvin Hernandez
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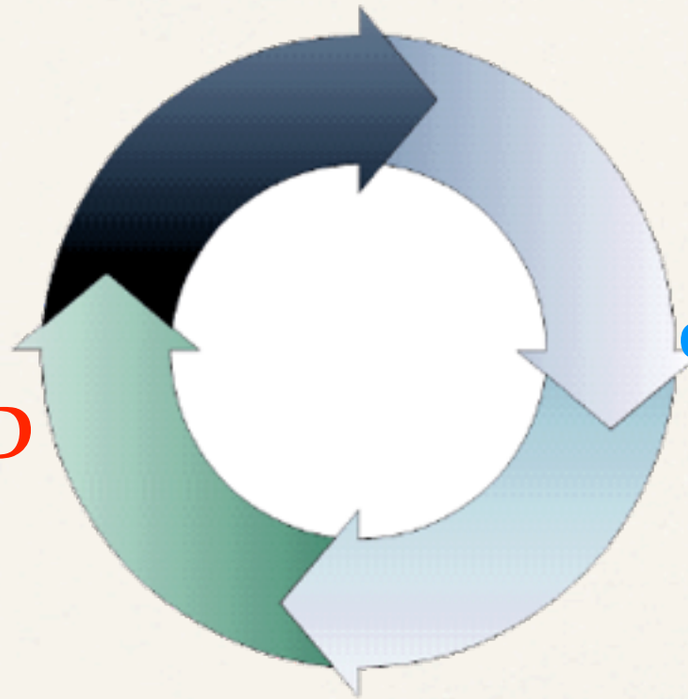
Philippe Meunier
Paul Steckler
Danny Yoo
and many many more people

Research & Teaching

Teaching
at all levels
K12, college, PhD



Research
on all aspects of
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