NKS Experimental Design and Implementation for Students

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An NKS 2004 Presentation




Introduction

- Experimentation is at the heart of NKS.
- Conducting general NKS experiments involves programming.
- Where can NKS and programming meet at the pre-college level?

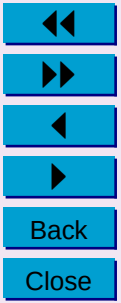



Pre-college

Two approaches to introducing NKS

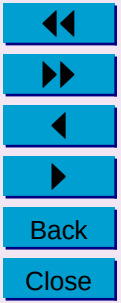
1. Computing courses: interesting problem domain
2. Domain courses (science,math):
   computer experiments that require programming

My Experience



Roadmap

- NKS Experimental Design
- Programming for NKS Experiments
- TeachScheme!
- Introductory NKS Exercise



NKS Experiments

Simple Programs

- CAs, Turing machines, substitution systems,
- numerical systems, multiway systems, and et cetera.

Experimentation

- Data generation
- Analysis (visual, statistical, etc.)

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Scientific Method for NKS

Textbook Scientific Method

1. Observation
2. Hypothesis
3. Experiment
4. Conclusion




Scientific Method for NKS

NKS Scientific Method

1. Observation
2. Question
3. Visualization
4. Experiment: Generation and Analysis
5. Conclusion




Beginning Programmers

Cognitive Model

Issues

- Syntax
- Errors
- Blank screen




Programming

- Language
- Environment
- Methodology

One language fits all?

- C?
- Java?
- Python?
- Scheme?
- Mathematica?




TeachScheme!

Less syntax, more problem solving

Pillars of TeachScheme!

- Curriculum
- Language Levels
- Programming Environment




Curriculum

- *How to Design Programs*

  Felleisen, Findler, Flatt, Krishnamurthi

  MIT Press, 2000

- `http://www.htdp.org`




Design Recipe

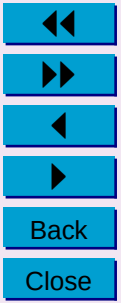
1. Problem Analysis & Data Definition
2. Contract, Purpose, Header
3. Examples
4. Function Template
5. Function Definition
6. Tests




Template matches Data Definition

```
A List-of-Number is one of:
  -- empty
  -- (cons Number List-of-Number)

;;Template
;;LON-f: List-of-Number -> ???
(define (LON-f a-lon)
  (cond
    [(empty? a-lon) ...]
    [(cons? a-lon) ...(first a-lon) ...
                   ...(LON-f (rest a-lon))]))
```



Language Levels

- Beginner through Advanced
- Better error reporting
- More pedagogic control
- Teachpacks

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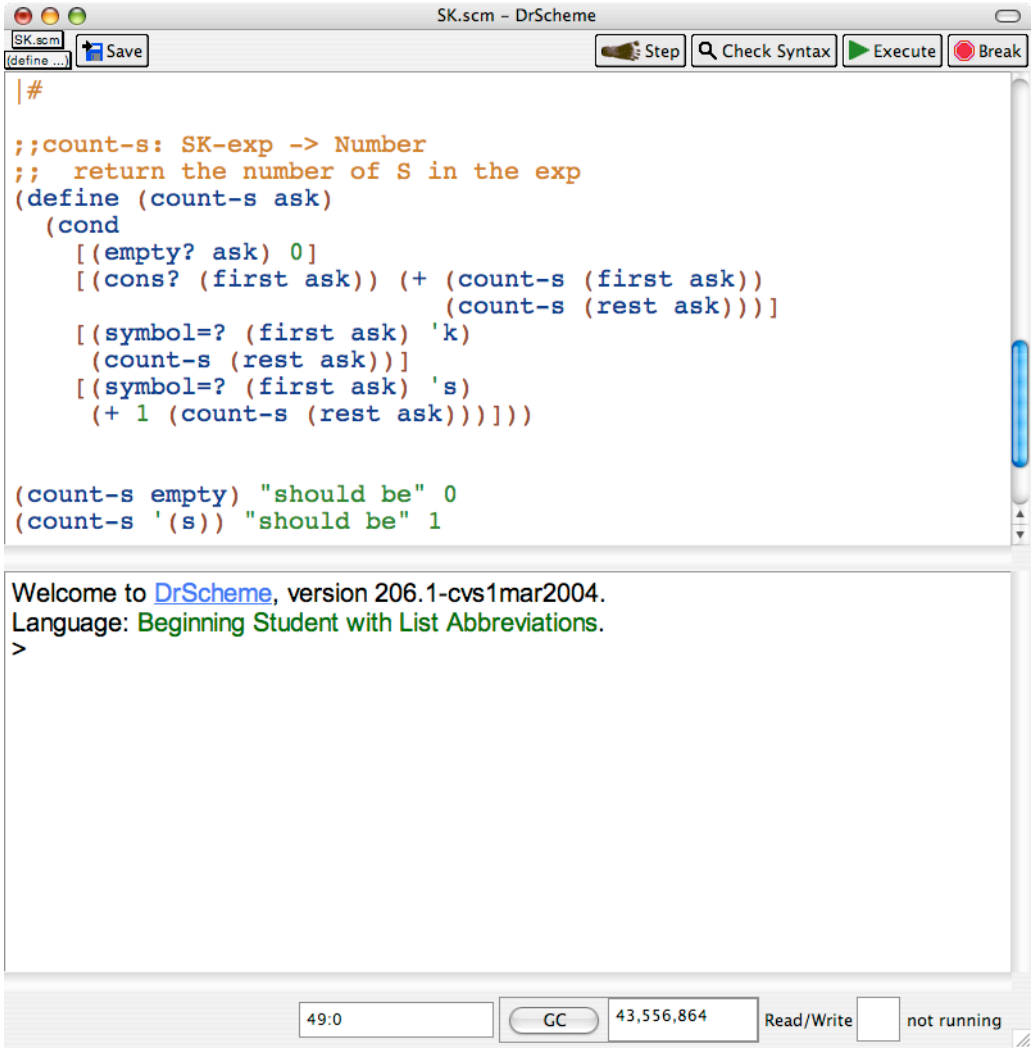
Programming Environment: DrScheme


SK.scm - DrScheme
SK.scm
(define ...)
Save
Step
Check Syntax
Execute
Break
|#
;;count-s: SK-exp -> Number
;; return the number of S in the exp
(define (count-s ask)
(cond
[(empty? ask) 0]
[(cons? (first ask)) (+ (count-s (first ask))
(count-s (rest ask)))]
[(symbol=? (first ask) 'k)
(count-s (rest ask))]
[(symbol=? (first ask) 's)
(+ 1 (count-s (rest ask)))]))
(count-s empty) "should be" 0
(count-s '(s)) "should be" 1
Welcome to DrScheme, version 206.1-cvs1mar2004.
Language: Beginning Student with List Abbreviations.
>
49:0
GC
43,556,864
Read/Write
not running

DrScheme

- Interactive
- Algebraic Stepper
- Syntax Checker
- Errors Matter!

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Introductory NKS Exercise

Analyze an arbitrarily complicated S-K combinator expression and produce the the number of Ss in the expression.

Extensions

- Statistics (e.g. distribution of S and K)
- Generation (create raw data)
- Compilation (combinators emulating other systems)




S-K Combinators

- Symbolic system (see NKS, pg 711)
- Two rules:

```
s[x_][y_][z_] -> x[z][y[z]]
k[x_][y_] -> x
```

- `s[s[k[s]][s[k[s[s[k][k]]]]][s[k[k]][s[s[s[s[s[k][k]]]]]]]`




Data Definition

```
An SK-Exp is one of:
  empty
  (cons 's SK-Exp)
  (cons 'k SK-Exp)
  (cons SK-Exp SK-Exp)
```




Contract/Purpose/Header

```
;;count-s: SK-exp -> Number
;;  return the number of S in the exp
(define (count-s ask) ...)
```




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Examples

```
(count-s empty) "should be" 0
(count-s '(s)) "should be" 1
(count-s '(s k s)) "should be" 2
(count-s '((s s k (s (s s k))) k)) "should be" 5
```




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Function Template

Reminder: Data Definition

```
An SK-Exp is one of:
  empty
  (cons 's SK-Exp)
  (cons 'k SK-Exp)
  (cons SK-Exp SK-Exp)
```

Template

```
(define (SK-fun ask)
  (cond
    [(empty? ask) ...]
    [(cons? (first ask)) ...(SK-fun (first ask))
                         ...(SK-fun (rest ask))...]
    [(symbol=? (first ask) 's)
      ...(first ask) ...(SK-fun (rest ask))...]
    [(symbol=? (first ask) 'k)
      ...(first ask) ...(SK-fun (rest ask))...]))
```

Function Body

```
(define (count-s ask)
  (cond
    [(empty? ask) 0]
    [(cons? (first ask))
       (+ (count-s (first ask)) (count-s (rest ask)))]
    [(symbol=? (first ask) 'k) (count-s (rest ask))]
    [(symbol=? (first ask) 's)
     (+ 1 (count-s (rest ask)))]))
```




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Testing

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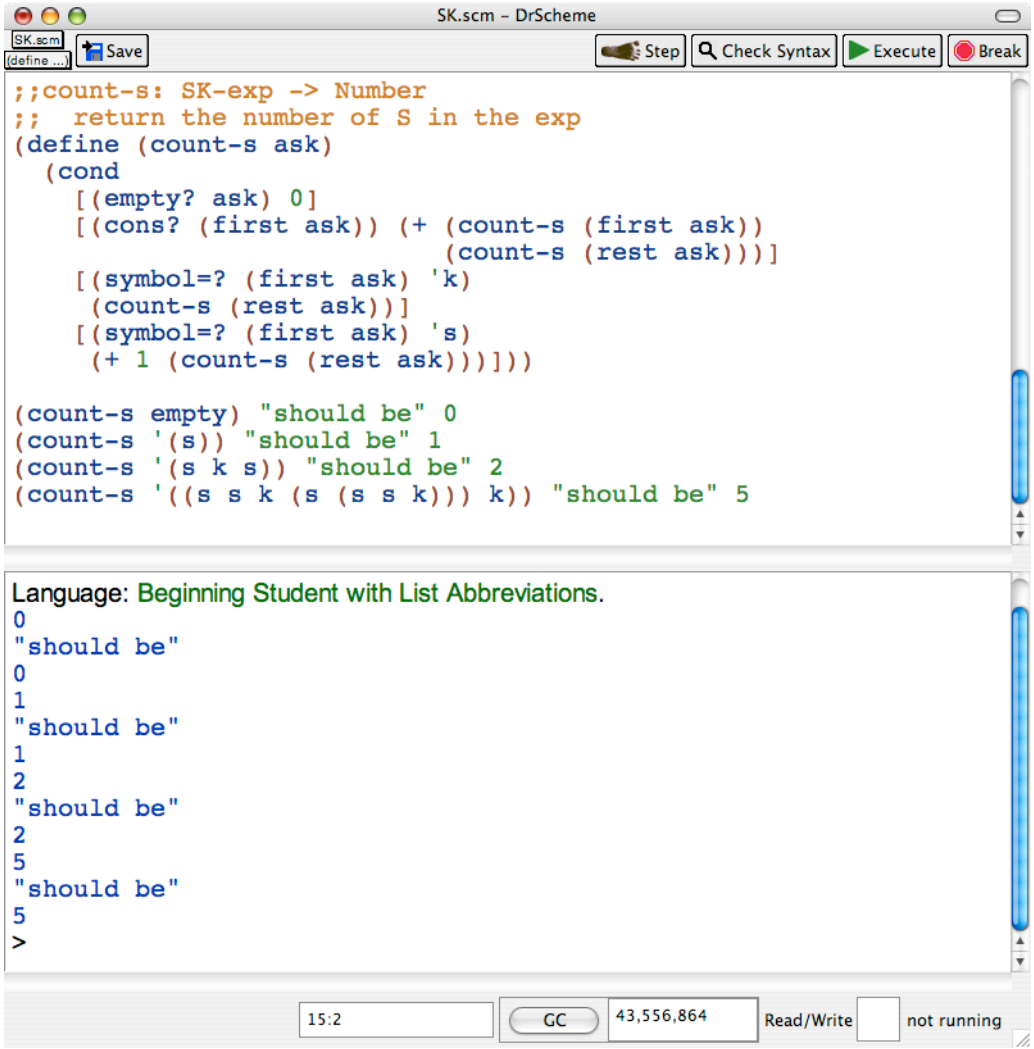
SK.scm - DrScheme
SK.scm
(define ...)
Save
Step
Check Syntax
Execute
Break
;;count-s: SK-exp -> Number
;; return the number of S in the exp
(define (count-s ask)
  (cond
    [(empty? ask) 0]
    [(cons? (first ask)) (+ (count-s (first ask))
                           (count-s (rest ask)))]
    [(symbol=? (first ask) 'k)
     (count-s (rest ask))]
    [(symbol=? (first ask) 's)
     (+ 1 (count-s (rest ask)))]))
(count-s empty) "should be" 0
(count-s '(s)) "should be" 1
(count-s '(s k s)) "should be" 2
(count-s '((s s k (s (s s k))) k)) "should be" 5
Language: Beginning Student with List Abbreviations.
0
"should be"
0
1
"should be"
1
2
"should be"
2
5
"should be"
5
>
15:2
GC
43,556,864
Read/Write
not running

S-K Combinators: Mathematica

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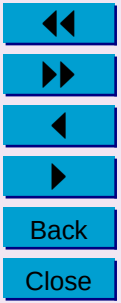
Data Definition

```
Data Definition
An SK-exp is one of:
  {}
  Prepend[SK-exp, "s"]
  Prepend[SK-exp, "k"]
  Prepend[SK-exp, SK-exp]
```

Examples

```
SCount [{}] === 0
SCount[{"S"}] === 1
SCount[{"S", "K"}] === 1
SCount[{"S", {"K"}}] === 1
SCount[{{"S", "S", "K", {"S" , {"S", "S", "K"}}}, "K"}]
  === 5
```



Body

```
Clear[SCount];
SCount[ske_] :=
  Which[
    ske == {}, 0,
    First[ske] === "S", 1 + SCount[Rest[ske]],
    First[ske] === "K", SCount[Rest[ske]],
    True, SCount[First[ske]] + SCount[Rest[ske]]];
```

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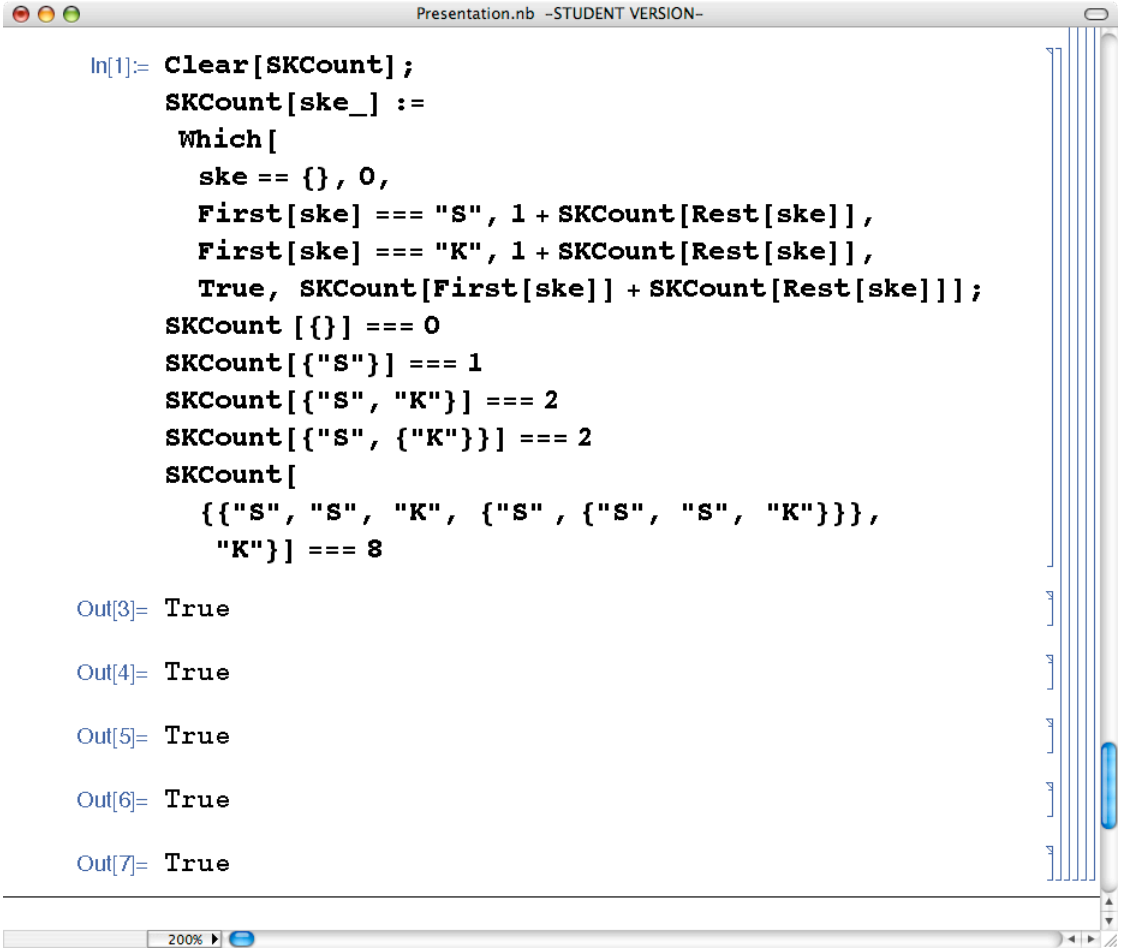
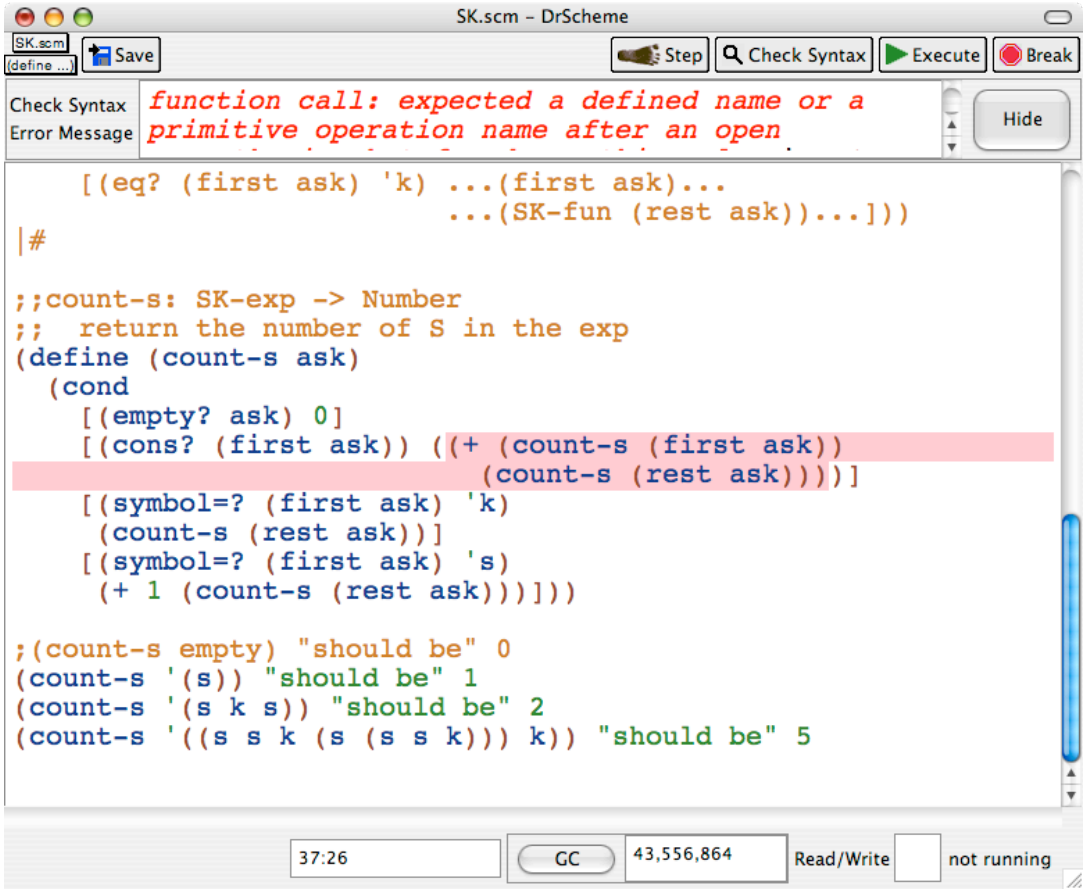
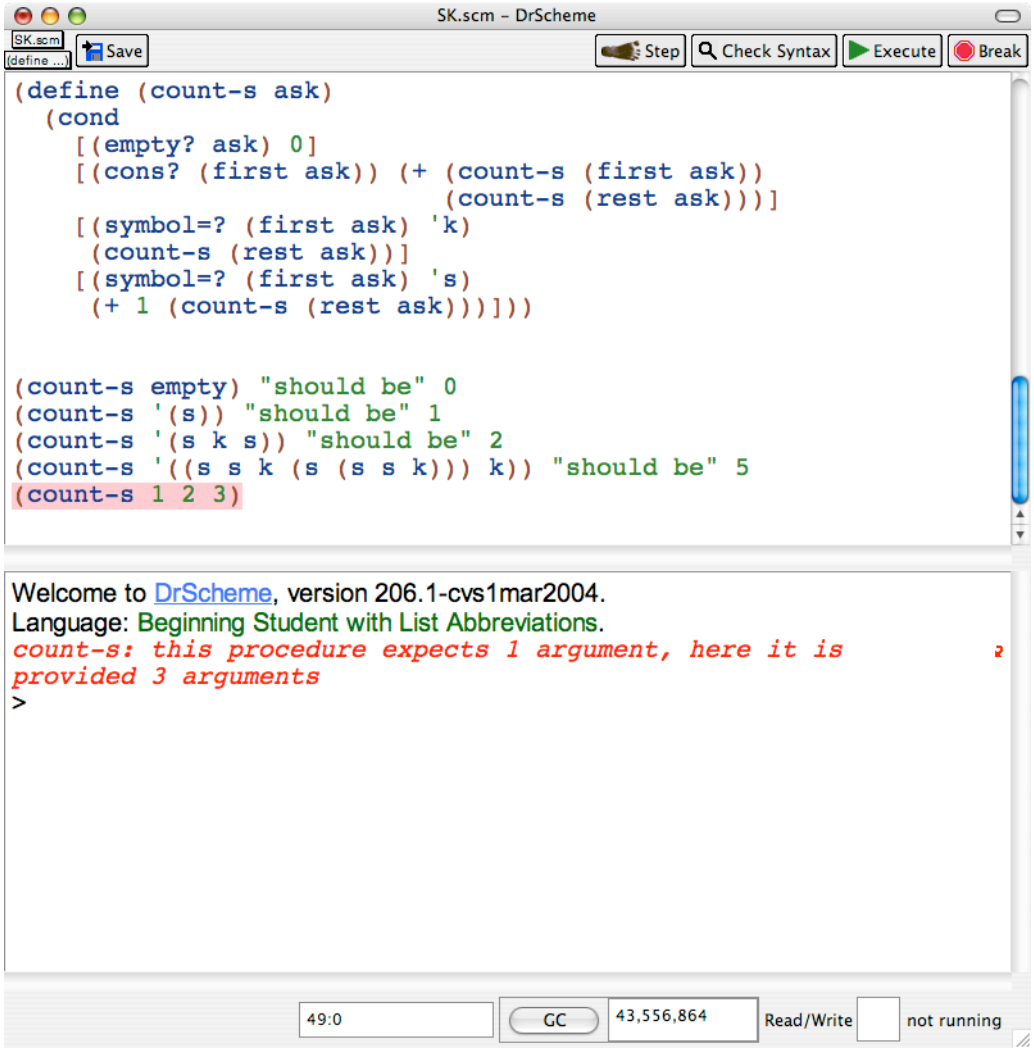
Testing

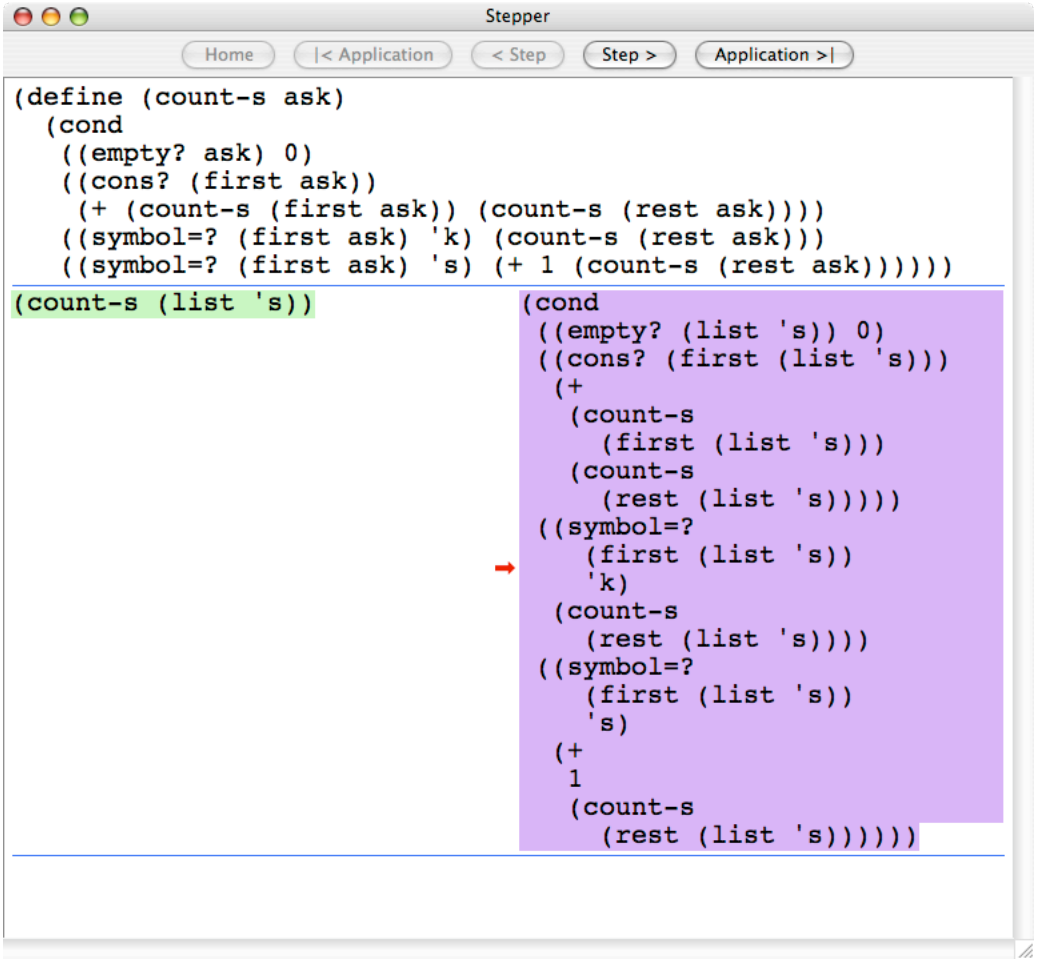

Presentation.nb -STUDENT VERSION-
In[1]:= Clear[SKCount];
SKCount[ske_] :=
Which[
ske == {}, 0,
First[ske] === "S", 1 + SKCount[Rest[ske]],
First[ske] === "K", 1 + SKCount[Rest[ske]],
True, SKCount[First[ske]] + SKCount[Rest[ske]]];
SKCount [{}] === 0
SKCount[{"S"}] === 1
SKCount[{"S", "K"}] === 2
SKCount[{"S", {"K"}}] === 2
SKCount[
{{"S", "S", "K", {"S" , {"S", "S", "K"}}},
"K"}] === 8
Out[3]= True
Out[4]= True
Out[5]= True
Out[6]= True
Out[7]= True
200%

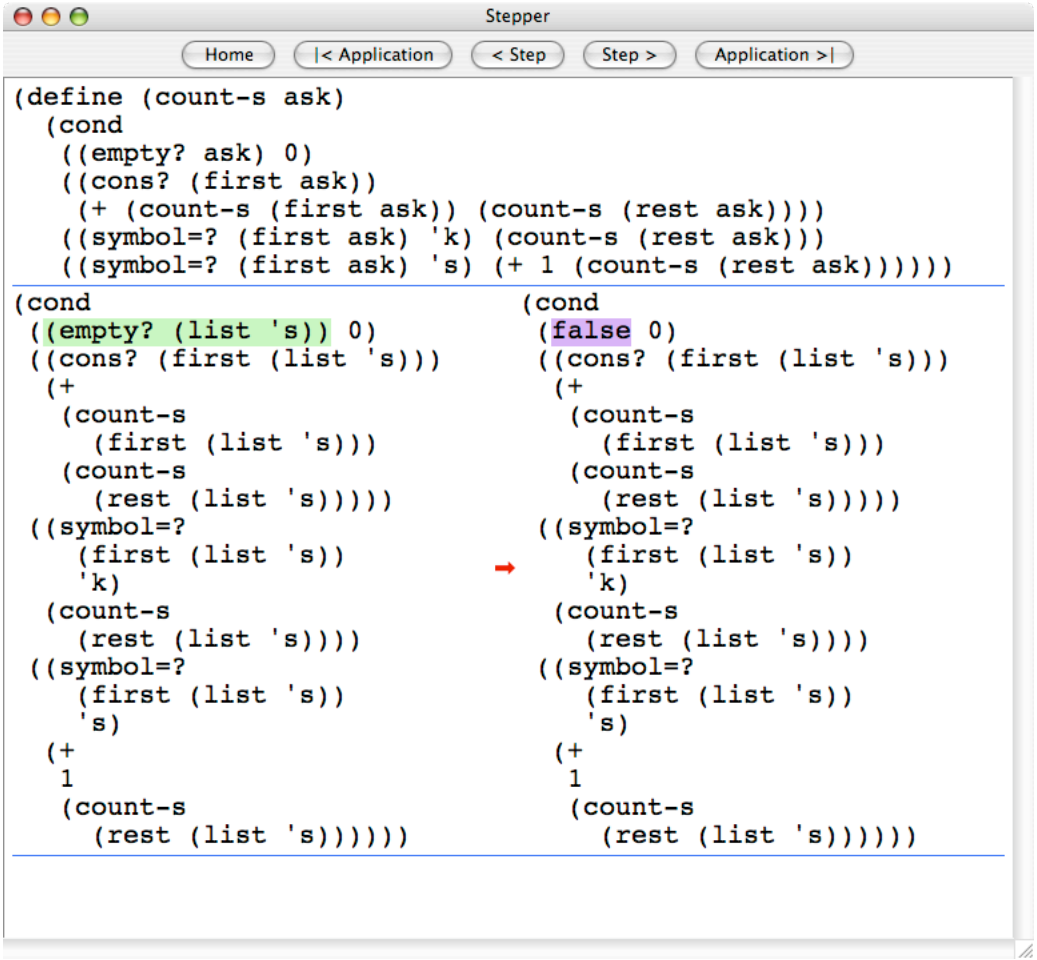
Errors


SK.scm – DrScheme
SK.scm
(define ...)
Save
Step
Check Syntax
Execute
Break
Check Syntax Error Message
function call: expected a defined name or a primitive operation name after an open
Hide
[(eq? (first ask) 'k) ...(first ask)...
...(SK-fun (rest ask))...]))
|#
;;count-s: SK-exp -> Number
;; return the number of S in the exp
(define (count-s ask)
(cond
[(empty? ask) 0]
[(cons? (first ask)) ((+ (count-s (first ask))
(count-s (rest ask))))]
[(symbol=? (first ask) 'k)
(count-s (rest ask))]
[(symbol=? (first ask) 's)
(+ 1 (count-s (rest ask)))]))
;(count-s empty) "should be" 0
(count-s '(s)) "should be" 1
(count-s '(s k s)) "should be" 2
(count-s '((s s k (s (s s k))) k)) "should be" 5
37:26
GC
43,556,864
Read/Write
not running


SK.scm – DrScheme
SK.scm
define ...
Save
Step
Check Syntax
Execute
Break
(define (count-s ask)
(cond
[(empty? ask) 0]
[(cons? (first ask)) (+ (count-s (first ask))
(count-s (rest ask)))]
[(symbol=? (first ask) 'k)
(count-s (rest ask))]
[(symbol=? (first ask) 's)
(+ 1 (count-s (rest ask)))]))
(count-s empty) "should be" 0
(count-s '(s)) "should be" 1
(count-s '(s k s)) "should be" 2
(count-s '((s s k (s (s s k))) k)) "should be" 5
(count-s 1 2 3)
Welcome to DrScheme, version 206.1-cvs1mar2004.
Language: Beginning Student with List Abbreviations.
count-s: this procedure expects 1 argument, here it is
provided 3 arguments
>
49:0
GC
43,556,864
Read/Write
not running

Stepper


Stepper
Home
|< Application
< Step
Step >
Application >|
(define (count-s ask)
(cond
((empty? ask) 0)
((cons? (first ask))
(+ (count-s (first ask)) (count-s (rest ask))))
((symbol=? (first ask) 'k) (count-s (rest ask)))
((symbol=? (first ask) 's) (+ 1 (count-s (rest ask))))))
(count-s (list 's))
(cond
((empty? (list 's)) 0)
((cons? (first (list 's)))
(+
(count-s
(first (list 's)))
(count-s
(rest (list 's)))))
((symbol=?
(first (list 's))
'k)
(count-s
(rest (list 's))))
((symbol=?
(first (list 's))
's)
(+
1
(count-s
(rest (list 's))))))


Stepper
Home
|< Application
< Step
Step >
Application >|
(define (count-s ask)
(cond
((empty? ask) 0)
((cons? (first ask))
(+ (count-s (first ask)) (count-s (rest ask))))
((symbol=? (first ask) 'k) (count-s (rest ask)))
((symbol=? (first ask) 's) (+ 1 (count-s (rest ask))))))
(cond
((empty? (list 's)) 0)
((cons? (first (list 's)))
(+
(count-s
(first (list 's)))
(count-s
(rest (list 's)))))
((symbol=?
(first (list 's))
'k)
(count-s
(rest (list 's))))
((symbol=?
(first (list 's))
's)
(+
1
(count-s
(rest (list 's))))))
(cond
(false 0)
((cons? (first (list 's)))
(+
(count-s
(first (list 's)))
(count-s
(rest (list 's)))))
((symbol=?
(first (list 's))
'k)
(count-s
(rest (list 's))))
((symbol=?
(first (list 's))
's)
(+
1
(count-s
(rest (list 's))))))

Concluding Thoughts

- Programming and NKS
- Little languages
- Future directions

http://www.ccs.neu.edu/home/raymond/TeachNKS