The TeachScheme! Project

Adelphi University
Brown University
Northeastern University
University of Chicago
University of Utah
Worcester Polytechnic Institute
The Revolution

Two principles:

Shift away from machine details

Emphasis on correctness over efficiency (ie, focus on program design)
What’s Wrong with Machine-Oriented Languages?

- Make students waste time on unimportant and uninteresting details
- Force students to confront issues they are not prepared for
- and ...

machine arithmetic, pointers and memory addresses, even i/o
What Computer Science is *Not* About

The computer!

Just as biology isn’t “microscope science” and writing isn’t “pen science” ...
What’s This About Program Design?

How do they know the load limit on bridges, Dad?

They drive bigger and bigger trucks over the bridge until it breaks.

Then they weigh the last truck and rebuild the bridge.
Why Am I Here?

- The TeachScheme! Project: Outreach program hosted by six universities
- Specially designed for high schools
- Provides all material -- books, software, etc -- free of charge
What Teachers Experience
K.I.S.S.
Keep It Simple Syntactically

C++/Pascal
10% Problem-solving vs 90% Syntax

Scheme
90% Problem-solving vs 10% Syntax
The Golden Rule of Scheme Syntax

( Operation List-of-Arguments )
or

( Operation Arg₁ )
The Golden Rule of Scheme Syntax

( Operation List-of-Arguments )
or

( Operation Arg₁ Arg₂ )
The Golden Rule of Scheme Syntax

( Operation List-of-Arguments )

or

( Operation Arg₁ Arg₂ . . . Argₙ )
An Example From Arithmetic

\[
\begin{array}{c}
4 + 5 \\
(\text{Operation} \quad \text{Arg}_1 \quad \text{Arg}_2)
\end{array}
\]
Example #1 (cont’d)

\[ 4 + 5 \]

\[
\left( \text{Operation} \quad \text{Arg}_1 \quad \text{Arg}_2 \right)
\]

\[
\left( \quad \right)
\]
Example #1 (cont’d)

```
( 4 + 5          )
( ( Operation Arg₁ Arg₂ )  )
( ( + )          )
```
Example #1 (cont’d)

\[
\begin{aligned}
( \text{Operation} & \quad \text{Arg}_1 \quad \text{Arg}_2 ) \\
( + & \quad 4 )
\end{aligned}
\]
Example #1 (cont’d)

4 + 5

( Operation \( \text{Arg}_1 \ \text{Arg}_2 \ )

( + 4 5 )
Example #1 (cont’d)

4 + 5

( + 4 5 )
Another Arithmetic Example

\[(4 + 5) \cdot 6\]
Example #2 (cont’d)

\[(4 + 5) \cdot 6\]
Example #2 (cont’d)

\[(4 + 5) \cdot 6\]

\[(\ast)\]
Example #2 (cont’d)

\[(4 + 5) \cdot 6\]

\[\left( * \left( + 4 5 \right) \right)\]
Example #2 (cont’d)

\[(4 + 5) \cdot 6\]

\[(* ( + 4 5 ) 6 )\]
Example #2 (cont’d)

\[(4 + 5) \cdot 6\]

\[(\ast (\, + \, 4 \, 5 \, ) \, 6 \, )\]
An Example From Algebra

\[ f(x) = x + 5 \]
Example #3 (cont’d)

\[ f(x) = x + 5 \]

( Operation  \( \arg_1 \)  \( \arg_2 \) )
Example #3 (cont’d)

\[ f(x) = x + 5 \]

( Operation Arg₁ Arg₂ )

( )
Example #3 (cont’d)

\[ f( x ) = x + 5 \]

( Operation Arg_1 Arg_2 )

( define )
Example #3 (cont’d)

\[ f(x) = x + 5 \]

( Operation \( \text{Arg}_1 \text{ Arg}_2 \) )
\[ \downarrow \]
( function-name \ input-name )
\[ \downarrow \]
( f x )
Example #3 (cont’d)

\[ f(x) = x + 5 \]

\[ (\text{Operation} \ Arg_1 \ Arg_2) \]

\[ (\text{define} \ (f \ x)) \]
Example #3 (cont’d)

\[ f(x) = x + 5 \]

( Operation Arg_1 Arg_2 )
↓
( output-rule )
↓
( + x 5 )
Example #3 (cont’d)

\[ f(x) = x + 5 \]

( Operation \( Arg_1 Arg_2 \) )

( define ( f x )
(  + x 5 ) )
Example #3 (cont’d)

\[
f(x) = x + 5
\]

( define ( f x )
  ( + x 5 ) )
Algebra vs Scheme vs Pascal

**Algebra**

\[ f(x) = x + 5 \]

**Scheme**

```scheme
(define (f x)
  (+ x 5))
```

**Pascal**

```pascal
Program f (Input, Output) ;
Var
  x : Integer ;
Begin
  Readln (x) ;
  Writeln (x + 5 )
End .
```
Design
D³: Data Drive Design
(A Non-Numeric Example)

Consider program guest, which determines whether a friend’s name is in a party’s invitation list.
Is *Mathilde* In The List?

- Mathilde
- John

No
Yes

Look in the **Rest of the List**
Is *Mathilde* In The Rest of the List?

- Mathilde
  - 
  - 
- Sherry
  - 
  -

No

Yes

Look in the Rest of the List
Pattern To Algebra
Algebra

guest ( name, list ) =
Algebra

\[ \text{guest}(\ name, \ list) = \]
\textit{guest}( \textit{name}, \textit{list} ) = \\
\quad \left\{ \begin{array}{l}
\text{if } \textit{list} \text{ is empty}
\end{array} \right\}
Algebra

$$\text{guest}(\text{name, list}) = \begin{cases} 
\text{no} & \text{if list is empty} 
\end{cases}$$
Algebra

\[
guest(\ name, \ list) =
\begin{cases}
  \text{no} & \text{if } list \text{ is empty} \\
  & \text{if } name = \text{first}(\ list) \\
\end{cases}
\]
Algebra

\[
guest(\ name, \ list ) = \\
\begin{cases} 
\text{no} & \text{if } list \text{ is empty} \\
\text{yes} & \text{if } name = \text{first}(\ list ) 
\end{cases}
\]
guest( name, list ) =
\begin{cases} 
  \text{no} & \text{if list is empty} \\
  \text{yes} & \text{if name = first ( list )} \\
  \text{otherwise} & 
\end{cases}
guest( name, list ) =

\begin{align*}
\text{no} & \quad \text{if list is empty} \\
\text{yes} & \quad \text{if name} = \text{first( list )} \\
guest(\ name, \ \text{rest} ( \ list )) & \quad \text{otherwise}
\end{align*}
Algebra

\[ \text{guest}( \text{name, list} ) = \]

Scheme

( define ( guest name list )

)
Algebra

\[
guest(\text{name, list}) = \\
\{ \\
\}
\]

Scheme

( define ( guest name list )

)
Algebra

\[ \text{guest}(\text{name, list}) = \{ \} \]

Scheme

\[
(\text{define}(\text{guest name list})
\begin{array}{l}
\text{(cond}
\end{array}
\begin{array}{l}
\text{(cond}
\end{array}
))
\]
Algebra

guest(name, list) =

\{
  \text{if } list \text{ is empty}
  \text{if } name = \text{first}(list)
  \text{otherwise}
\}

Scheme

(define (guest name list)
  (cond
    ))
**Algebra**

\[
guest(\text{name}, \text{list}) =
\begin{cases}
\text{if list is empty} \\
\text{if name = first(list)} \\
\text{otherwise}
\end{cases}
\]

**Scheme**

\[
(\text{define}(\text{guest name list})
(\text{cond}
(\
( ) )
( )
( ) )))
\]
Algebra

guest( name, list ) =

\{ 
  if list is empty
  if name = first( list )
  otherwise
\}

Scheme

( define ( guest name list )
  ( cond
    ( ( empty? list )
    ( ( equal? name ( first list )
    ( else
      ) )
      ) )
      ) )
**Algebra**

\[
guest(\text{ name, list }) =
\begin{cases}
\text{no} & \text{if list is empty} \\
\text{yes} & \text{if name} = \text{first (list)} \\
guest(\text{ name, rest (list)}) & \text{otherwise}
\end{cases}
\]

**Scheme**

\[
(define (guest name list)
  (cond
    ((empty? list) 'no)
    ((equal? name (first list)) 'yes)
    (else (guest name (rest list))))
)\]
Did You Notice?
**Algebra**

\[
guest(\text{name, list}) =
\begin{cases}
\text{no} & \text{if list is empty} \\
\text{yes} & \text{if name} = \text{first(list)} \\
\text{guest(name, rest(list))} & \text{otherwise}
\end{cases}
\]

**Scheme**

\[
(\text{define} \ (\text{guest name list})
\begin{cases}
(\text{cond}) \\
(\ (\text{empty? list})) & \text{'no}) \\
(\ (\text{equal? name (first list})) & \text{'yes}) \\
(\text{else}) & (\text{guest name (rest list)})
\end{cases})
\]
Recursion Is Natural
Comparisons
Program NameOnList (Input, Output);

Type
  ListType = ^NodeType;
  NodeType = Record
    First : String;
    Rest : ListType
  End;

Var
  List : ListType;
  Name : String;

Procedure GetList (Var List: ListType);

Function Guest (Name : String; List : ListType) : String;
Begin
  If List = nil
    Then Guest := 'no'
  Else If Name = List^.First
    Then Guest := 'yes'
    Else Guest := Guest ( Name, List^.Rest)
End;

Begin
  Readln ( Name );
  GetList ( List );
  Writeln (Guest ( Name, List ) )
End.
Program NameOnList (Input, Output);

Type
  ListType = ^NodeType;
  NodeType = Record
    First : String;
    Rest : ListType
  End;

Var
  List       : ListType;
  Name    : String;

Procedure GetList (Var List: ListType); . . .

Function Member (Name : String;  List : ListType) : String;
Begin
  If List = nil
    Then Member := 'no'
  Else If Name = List^.First
    Then Member := 'yes'
  Else Member := Member ( Name, List^.Rest)
End;

Begin
  Readln ( Name );
  GetList ( List );
  Writeln (Member ( Name, List ) )
End .

Pascal

(define (guest name list)
  (cond
    ((empty? list) no)
    ((equal? name (first list)) yes)
    (else (guest name (rest list))))

Scheme

(define (guest name list)
  (cond
    ((empty? list) no)
    ((equal? name (first list)) yes)
    (else (guest name (rest list))))

Procedure GetList (Var List: ListType); . . .

Function Member (Name : String;  List : ListType) : String;
Begin
  If List = nil
    Then Member := 'no'
  Else If Name = List^.First
    Then Member := 'yes'
  Else Member := Member ( Name, List^.Rest)
End;

Begin
  Readln ( Name );
  GetList ( List );
  Writeln (Member ( Name, List ) )
End .
```c
#include <stdio.h>
typedef struct listCell * list;
struct listCell {
    int  first;
    list rest;
};
bool guest (int x, list l) {
    if (l == NULL)
        return false;
    else if (x == (l --> first))
        return true;
    else
        return guest (x, l --> rest);
}
int main (int argc, char **argv) {
    list l1, l2, l3 = NULL; int x;
    l1 = (list) malloc ((sizeof (struct listCell)));
    l2 = (list) malloc ((sizeof (struct listCell)));
    l1 --> first = 2; l1 --> rest = l2;
    scanf("%d", &x);
    printf("%d\n", member (x, l1));
}
```

```scheme
(define (guest name list)
  (cond
    ((empty? list) 'no)
    ((equal? name (first list)) 'yes)
    (else (guest name (rest list)))))
```
Principles of Program Design

• K.I.S.S.: Keep It Simple Syntactically
• $D^3$: Data Drive Design
• Recursion Is Natural
The Ping-Pong Game

9th Graders With

- Algebra I
- 12 Weeks of Scheme
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The Programming Environment

Salient DrScheme features:

• interactive evaluation
• immediate error-reporting with source highlighting
• language presented as a sequence of increasingly complex layers
Putting it in Context
What a University Saw

Universities like Rice admit some of the best students in the nation; yet, the students cannot

• develop a program systematically
• separate problem solving from machine details
• explain why a program works (or doesn’t)
What the ETS Wishes You Didn’t Know (~1998)
Conclusion

• Computer science education is undergoing a revolution

• TeachScheme! is at the forefront

• Schools and universities must collaborate to reap the benefits
What We Offer

- Textbook (*How to Design Programs*)
- DrScheme programming environment
- Teacher’s guide
- Programming environment guide
- Exercises and solution sets
- Miscellany: help, summer course, etc

All available for free!
Web Information

See

http://www.teach-scheme.org/

for information about the project, especially the free summer courses