

# **Teaching Software Testing by Encouraging Contributions to an Open Source Web-based System for the Assessment of Programming**

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## Outline

- Pedagogical Context
- Systems for Automated Assessment of Programming Assignments
- WeBWork
- WeBWork-JAG
- Students' Contributions to WeBWork
- Conclusions and Future Work

## Pedagogical Context

- Programming is the first skill a computer science major is expected to master
- Programming fundamentals are taught in CS1 and CS2 courses [CC2005]
  - Fundamental programming constructs, algorithms and problem solving, elementary data structures, recursion, event-driven programming
- Open source for early exposure to collaborative and community-driven development
- Test-driven development for emphasizing the criticality of formulating requirements in a testable manner and laying the basis for quality coding
- Peer-review for giving students an awareness of the value of getting an independent person to examine code and detect errors before release and use by others

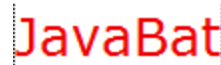
## Systems for Automated Assessment of Programming Assignments

- Web-based systems to encourage practice (with feedback), and improve and reinforce students' understanding of concepts
- Types of questions
  - True / false, short answer, multiple-choice, programming
- Grading programs
  - Correctness + quality + authenticity

# WeBWork in CS

## Existing Systems

- **BOSS** [www.dcs.warwick.ac.uk/boss](http://www.dcs.warwick.ac.uk/boss)
- **CodeLab** [www.turingscraft.com](http://www.turingscraft.com)
- **CourseMarker** [www.cs.nott.ac.uk/CourseMarker](http://www.cs.nott.ac.uk/CourseMarker)
- **Gradiance** [www.gradiance.com](http://www.gradiance.com)
- **JavaBat** [www.javabat.net](http://www.javabat.net)
- **MyCodeMate** [www.mycodemate.com](http://www.mycodemate.com)
- **OWL** [owl.course.com](http://owl.course.com)
- **Viope** [www.viope.com](http://www.viope.com)



## WeBWork

- *webwork.rochester.edu*
- Project funded by NSF
- Free, open-source and web-based
- Automated problem delivery and grading
- Initial development and applications in the fields of mathematics and physics
- Currently in use at more than 50 colleges and universities

## WeBWork

- Problems are written in the Problem Generating macro language (PG)
  - Text, HTML, Latex, Perl
- Underlying engine dedicated to dealing with mathematical formulae
  - $x+1 = (x^2-1)/(x-1) = x+\sin(x)^2+\cos(x)^2$
- Individualized and parameterized versions of problems

## WeBWork for Programming Fundamentals

- *atlantis.seidenberg.pace.edu/webwork2/demo*
- True / false, short answer and multiple choice problems for Java, Python and SML
- Extension of WeBWork for use in programming fundamentals
- Evaluation of Java program fragments by interfacing WeBWork with JUnit [*www.junit.org*]
  - WeBWork-JAG = WeBWork + **JUnit**

# WeBWork in CS

WeBWork : PPPJdemo : set1 : 1 - Mozilla Firefox

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WeBWork : PPPJdemo : set1 : 1

WeBWork

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Main Menu

Courses  
Homework Sets  
set1  
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Problems

Problem 1  
Problem 2

Display Options

View equations as:

plainText  
 formattedText  
 images  
 jsMath  
 asciimath

Show saved answers?  
 Yes  No

Apply Options

WeBWork => PPPJdemo => set1 => 1

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## set1: Problem 1

### SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called *sumEven* and must:

- Be declared public and static;
- Take one parameter of type *int* representing the limit;
- Return an *int* containing the sum; and
- Throw an *IllegalArgumentException* for an argument strictly smaller than 0.

Preview Answers Submit Answers

You have attempted this problem 0 times.  
You have unlimited attempts remaining.

Email instructor

# WeBWorK in CS

The screenshot shows a web browser window titled "WeBWorK : PPPJdemo : set1 : 1 - Mozilla Firefox". The page header includes the WeBWorK logo and the text "Logged in as christelle. Log Out". The main navigation menu on the left includes "Courses", "Homework Sets", "set1", "Problem 1", "Password/Email", "Grades", and "Report bugs". The current page is "set1: Problem 1".

The problem content is as follows:

WebWork => PPPJdemo => set1 => 1

▲Prob. List    Next ▶

### set1: Problem 1

Entered	Answer Preview	Messages
<pre>public static int sumEven(int n) { if (n &gt;= 0) { int res = 0; for (int i = 0; i &lt;= n; i++) { if (i % 2 == 0) res = res + i; } return res; } throw new IllegalArgumentException("Argument " + n + " not in range"); }</pre>		Good Work!

The above answer is correct.

### SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called *sumEven* and must:

- Be declared public and static;
- Take one parameter of type int representing the limit;
- Return an int containing the sum; and
- Throw an *IllegalArgumentException* for an argument strictly smaller than 0.

```
public static int sumEven(int n) {
    if (n >= 0) {
        int res = 0;
        for (int i = 0; i <= n; i++) {
            if (i % 2 == 0)
                res = res + i;
        }
    }
}
```

# WeBWork in CS

WebWork : PPPJdemo : set1 : 1 - Mozilla Firefox

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WeBWork

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- Problem 2

Display Options

View equations as:

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- asciimath

Show saved answers?

- Yes
- No

WebWork => PPPJdemo => set1 => 1

▲Prob. List Next ►

## set1: Problem 1

Entered	Answer Preview	Messages
<pre>public static int sumEven(int n) { if (n &gt;= 0) { int res = 0; for (int i = 0; i &lt;= n; i++)     { if (i % 2 == 0) res = res + i } return res; } throw new     IllegalArgumentException("Argument " + n + " not in range"); }</pre>		Compile error: SumEvenNumbers.java:18: ';' expected } ^ 1 error

The above answer is NOT correct.

### SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called *sumEven* and must:

- Be declared public and static;
- Take one parameter of type *int* representing the limit;
- Return an *int* containing the sum; and
- Throw an *IllegalArgumentException* for an argument strictly smaller than 0.

```
public static int sumEven(int n) {
```

# WeBWork in CS

WebWork : PPPJdemo : set1 : 1 - Mozilla Firefox

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WebWork : PPPJdemo : set1 : 1

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Show saved answers?

- Yes  No

WeBWork => PPPJdemo => set1 => 1

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## set1: Problem 1

Entered	Answer Preview	Messages
<pre>public static int sumEven(int n) { int res = 0; for (int i = 0; i &lt;= n; i++) { if (i % 2 == 0) res = res + i; } return res; }</pre>		You only got 9 out of 11 tests right. You need to work on: * Test failed for input = -5 - The method should return an <code>IllegalArgumentException</code> for negative numbers! * Test failed for input = -1 - The method should return an <code>IllegalArgumentException</code> for negative numbers!

The above answer is NOT completely correct.

### SUM OF EVEN NUMBERS

Write a method that computes the sum of the even numbers from 0 to a given limit (included).

The method will be called `sumEven` and must:

- Be declared public and static;
- Take one parameter of type `int` representing the limit;
- Return an `int` containing the sum; and
- Throw an `IllegalArgumentException` for an argument strictly smaller than 0.

```
public static int sumEven(int n) {  
    int res = 0;
```

## Contributing to WeBWork

- Students' contributions to WeBWork
  - WeBWork-JAG questions (Java + JUnit)
- Contributed questions were peer-reviewed and tested by students, and then integrated in the WeBWork library of problems by the instructors

## Contributing to WeBWoRk – Students' Results

- WeBWoRk-JAG questions
  - Poor formulation of the questions (scope not clear, modifiers not stated, requirement for the use of a specific algorithm)
  - Well-written test cases for method signatures
  - Not exhaustive test cases for the method (null object, equivalence class identification, exceptions, invalid inputs, no white box testing)
  - Coarse or inexistent feedback for failure test cases
  - Crucial role of QA to catch problems

## Contributing to WeBWork – Students' Feedback

- When specifying the question students had the user in mind (not so much when writing the tests)
- Students became familiar with the use of the Reflection API
- Writing WeBWork-JAG questions forced students to think about testing first
- Students improved their testing skills (including regression testing)

## Conclusions and Future Work

- Development of a novel pedagogy encouraging students to contribute their own questions to the system WeBWork library and introducing them to crucial practices of software engineering
- Create a community of contributors to monitor quality, share work and extend the WeBWork library
- Stay tuned...
  - WeBWork workshop at Pace University in the spring 2008

## Acknowledgements

- NSF CCLI AI Grants “*Collaborative Research: Adapting and Extending WeBWork for Use in the Computer Science Curriculum*” #0511385 and #0511391
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  - Jacqueline Baldwin, Nathan Baur (JUnit extension)
  - Sophal Chiv (inputing problems and help desk)
  - Eileen Crupi, Tabitha Estrellado (inputing problems)
  - Allyson Ortiz, Veronica Portas (existing systems)
  - Yue Ma (testing)