CSC 405
Dynamic Web Pages

Aleksandr Nahapetyan
anahape@ncsu.edu
(Slides adapted from Dr. Kapravelos)

Class Objectives

- How do we make the web dynamic?
- In JavaScript, everything is an _____ !
- T/F You can validate forums only on the client-side
- What are some ways JavaScript lets you execute code dynamically?
  - How does this make analysis harder?
- What does the JavaScript engine execute?
- How do we make it fast?

In the beginning…

In the beginning…

HTML was static!

Yahoo! Deutschland CLICK HERE TO VISIT THE STARS YAHOO! LOS ANGELES Weekly Picks

Search Options

Yellow Pages - People Search - City Maps -- News Headlines - Stock Quotes - Sports Scores

- **Arts** - - *Humanities*, *Photography*, *Architecture*, *...*
- **Business and Economy** **[Xtra!]** - - *Directory*, *Investments*, *Classifieds*, *...*
- **Computers and Internet** **[Xtra!]** - - *Internet*, *WWW*, *Software*, *Multimedia*, *...*
- **Education** - - *Universities*, *K-12*, *Courses*, *...*
- **Entertainment** **[Xtra!]** - - *TV*, *Movies*, *Music*, *Magazines*, *...*
- **Government** - - *Politics* ***[Xtra!]***, *Agencies*, *Law*, *Military*, *...*
- **Health** **[Xtra!]** - - *Medicine*, *Drugs*, *Diseases*, *Fitness*, *...*
- **News** **[Xtra!]** - - *World* ***[Xtra!]***, *Daily*, *Current Events*, *...*
- **Recreation and Sports** **[Xtra!]** - - *Sports*, *Games*, *Travel*, *Autos*, *Outdoors*, *...*
- **Reference** - - *Libraries*, *Dictionaries*, *Phone Numbers*, *...*
- **Regional** - - *Countries*, *Regions*, *U.S. States*, *...*
- **Science** - - *CS*, *Biology*, *Astronomy*, *Engineering*, *...*
- **Social Science** - - *Anthropology*, *Sociology*, *Economics*, *...*
- **Society and Culture** - - *People*, *Environment*, *Religion*, *...*

Yahoo! New York - Yahoo! Shop - Yahooligans!

Yahoo! Japan - Yahoo! Internet Life - Yahoo! San Francisco

Source: https://web.archive.org/web/19961017235908/http://www2.yahoo.com/

Welcome to Amazon.com Books!

One million titles, consistently low prices.

(If you explore just one thing, make it our personal notification service. We think it's very cool!)

Spotlight! -- August 16th

These are the books we love, offered at Amazon.com low prices. The spotlight moves **EVERY** day so please come often.

One Million Titles

Search Amazon.com's million title catalog by author, subject, title, keyword, and more... Or take a look at the books we recommend in over 20 categories... Check out our customer reviews and the award winners from the Hugo and Nebula to the Pulitzer and Nobel... and bestsellers are 30% off the publishers list...

Eyes & Editors, a personal notification service

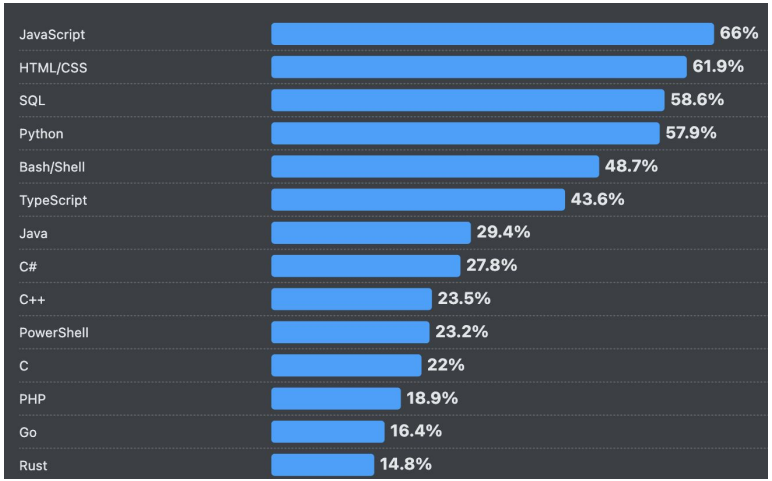
Like to know when that book you want comes out in paperback or when your favorite author releases a new title? Eyes, our tireless, automated search agent, will send you mail. Meanwhile, our human editors are busy previewing galleys and reading advance reviews. They can let you know when especially wonderful works are published in particular genres or subject areas. Come in, meet Eyes, and have it all explained.

Your Account

Check the status of your orders or change the email address and password you have on file with us. Please note that you **do not** need an account to use the store. The first time you place an order, you will be given the opportunity to create an account.

PHP: PHP: Hypertext Preprocessor

- Developed in 1993, Personal Home Page/Forms Interpreter
- Weak types, dynamic! What could possibly go wrong.
- Simple syntax that lets you modify the HTML on the server side
- Modern frameworks recommended!
- If you are unsure what the function does, check the manual



PHP

```php
<?php
$ua = $_SERVER['HTTP_USER_AGENT'];

if (str_contains($ua, 'Firefox')) {
    $browser = 'Firefox';
} elseif (str_contains($ua, 'Chrome')) {
    $browser = 'Chrome';
} elseif (str_contains($ua, 'Safari')) {
    $browser = 'Safari';
} else {
    $browser = 'Unknown';
}

echo "Hello, $browser!";
```

Source: https://web.archive.org/web/19981202230410/http://www.google.com/

Dynamic HTML

- However, people soon realized that we could have websites interact with users based on inputs

JavaScript

- Client-Side scripting language for interacting and manipulating HTML
- Created by Brendan Eich at Netscape Navigator 2.0 in September 1995 as "LiveScript"
- Renamed to "JavaScript" in December 1995
- By August 1996, Microsoft added support for JavaScript to Internet Explorer
  - Microsoft later changed the name to JScript to avoid Sun's Java trademark
- Submitted to ECMA International for standardization on November 1996
- ECMA-262, on June 1997, standardized first version of ECMAScript

JavaScript

- Lingua franca of the web
  - bridge language allowing users to execute code
- Eventually supported by all browsers
- Language organically evolved along the way

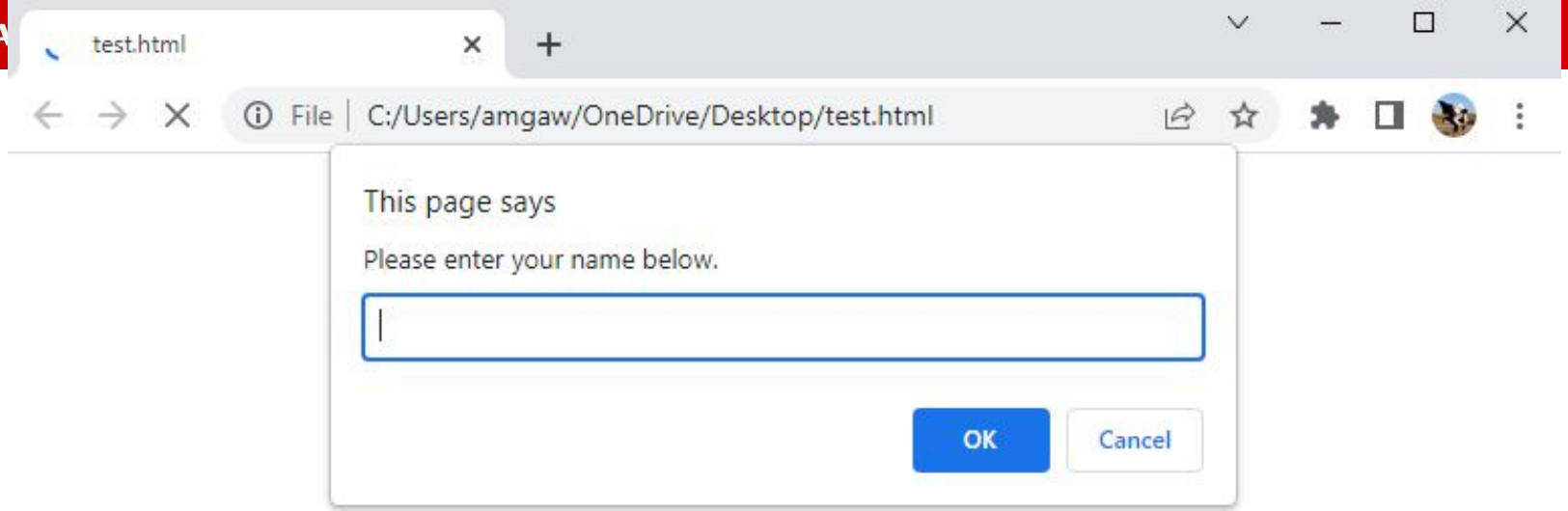
JavaScript

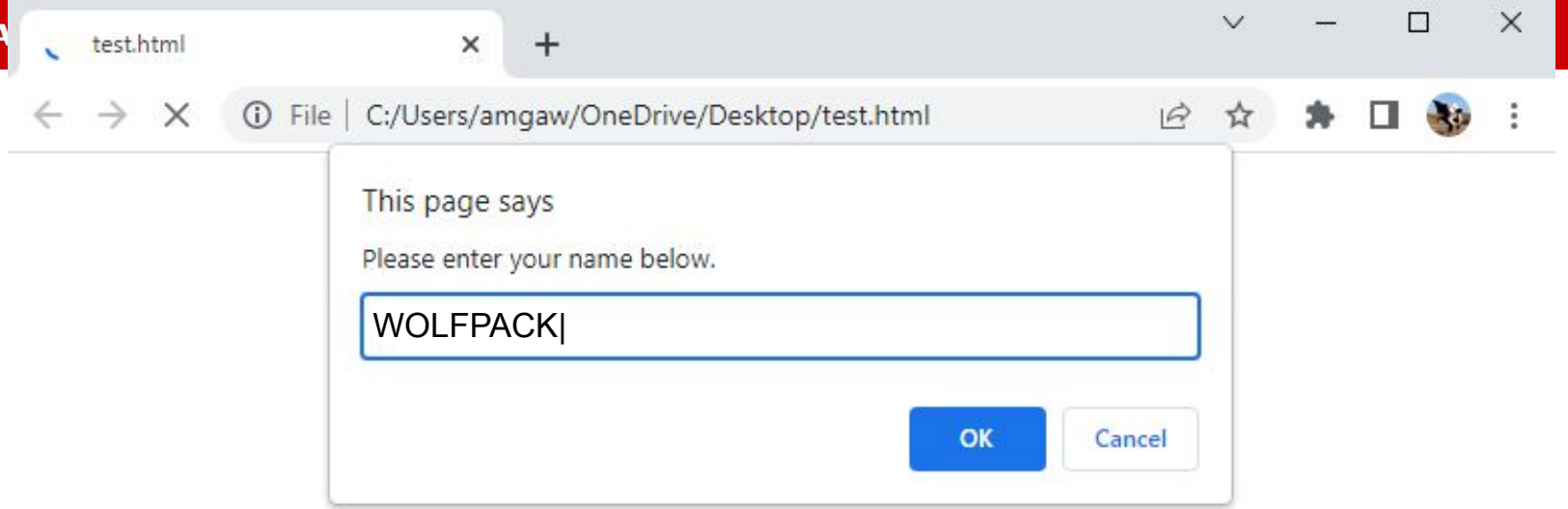
- Code can be embedded into HTML pages using the `script` element and (optionally storing the code in HTML comments)

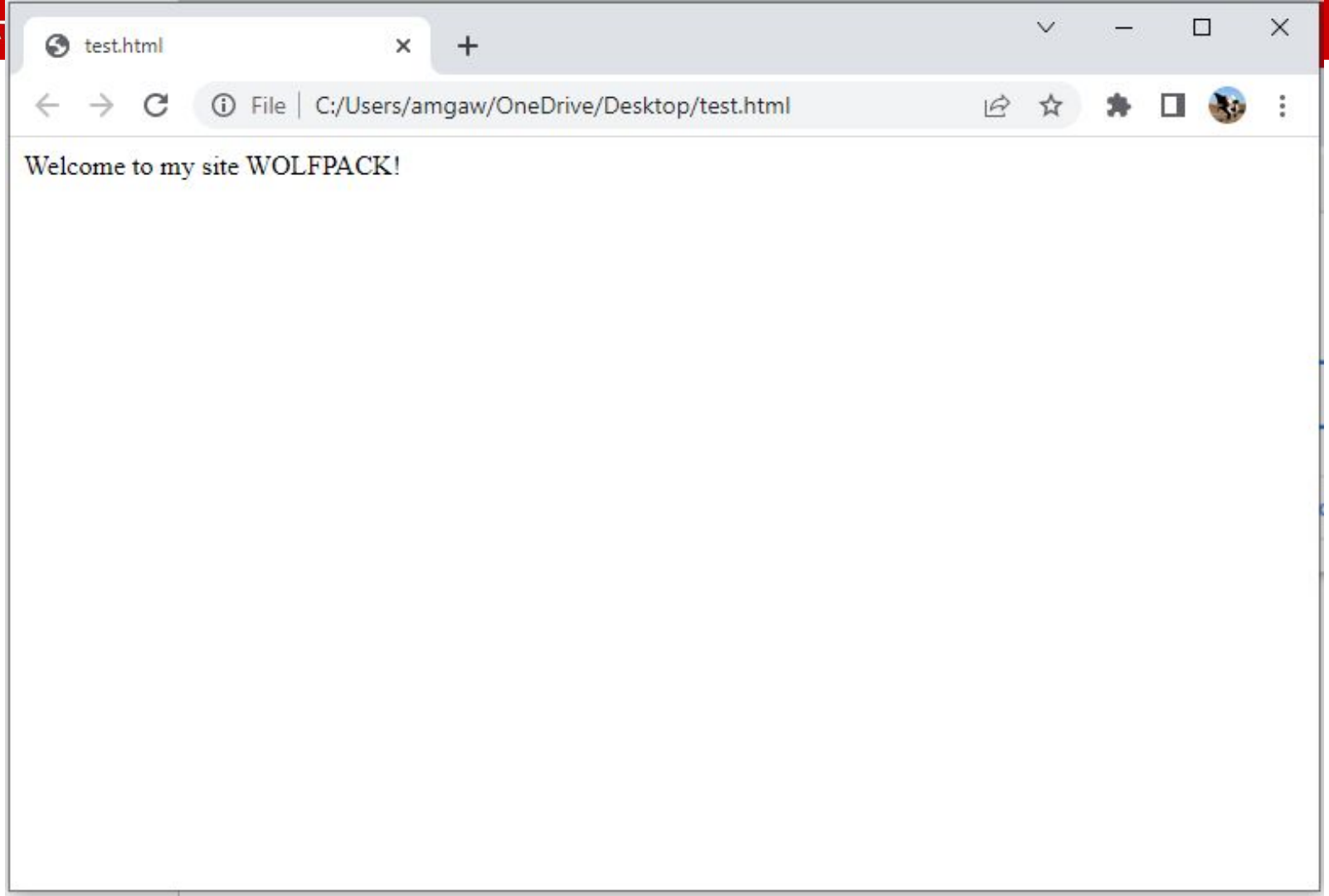
```
<script>
var name = prompt('Please enter your name below.', '');
if (name == null) {
  document.write('Welcome to my site!');
} else {
  document.write('Welcome to my site ' + name + '!');
}
</script>
```

```
<script type="text/javascript">
<script language="javascript">
<script src="js/html2canvas.js">
```

Alternative Implementations


test.html
File | C:/Users/amgaw/OneDrive/Desktop/test.html
This page says
Please enter your name below.
OK
Cancel


test.html
File | C:/Users/amgaw/OneDrive/Desktop/test.html
This page says
Please enter your name below.
WOLFPACK
OK
Cancel


test.html
File | C:/Users/amgaw/OneDrive/Desktop/test.html
Welcome to my site WOLFPACK!

JavaScript

- You can also include external JavaScript files in your HTML
  - As opposed to the inline JavaScript that we saw in the previous example

- `<script src="js/html2canvas.js">`
- When the browser parses this HTML element, it automatically fetches and executes the JavaScript before continuing to parse the rest of the HTML
  - Can also place at the **end** of HTML in case you want to render content, **then** execute off it
  - Placement of JS **matters**

DOM Example

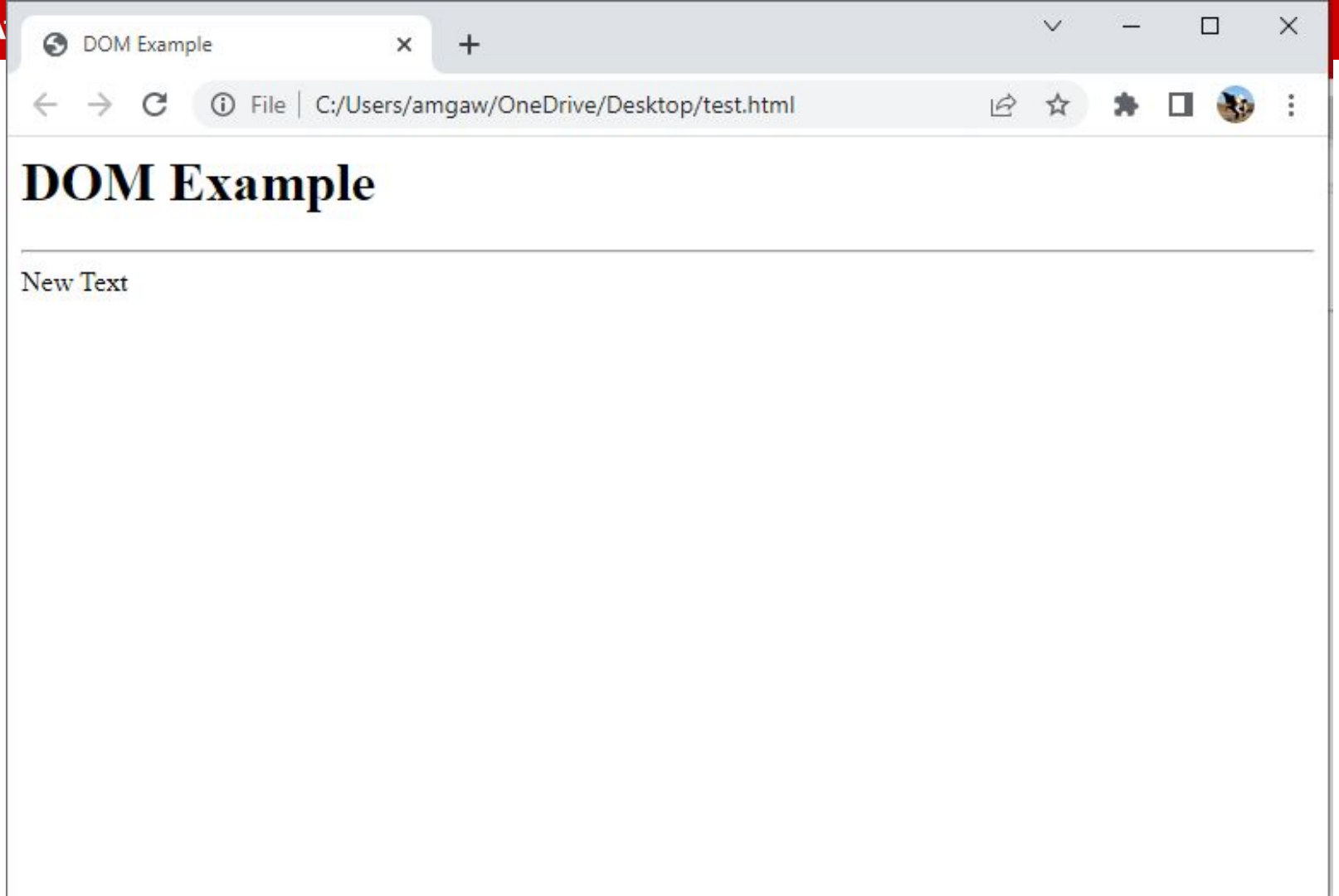
```
<html>
 <head>
   <meta charset="UTF-8">
   <title>DOM Example</title>
 </head>
 <body>
  <h1>DOM Example</h1>
  <hr>
  <div id='insert_here'>Original Text</div>
 </body>
 <script>
   document.getElementById('insert_here').innerText = "New Text";
 </script>
</html>
```

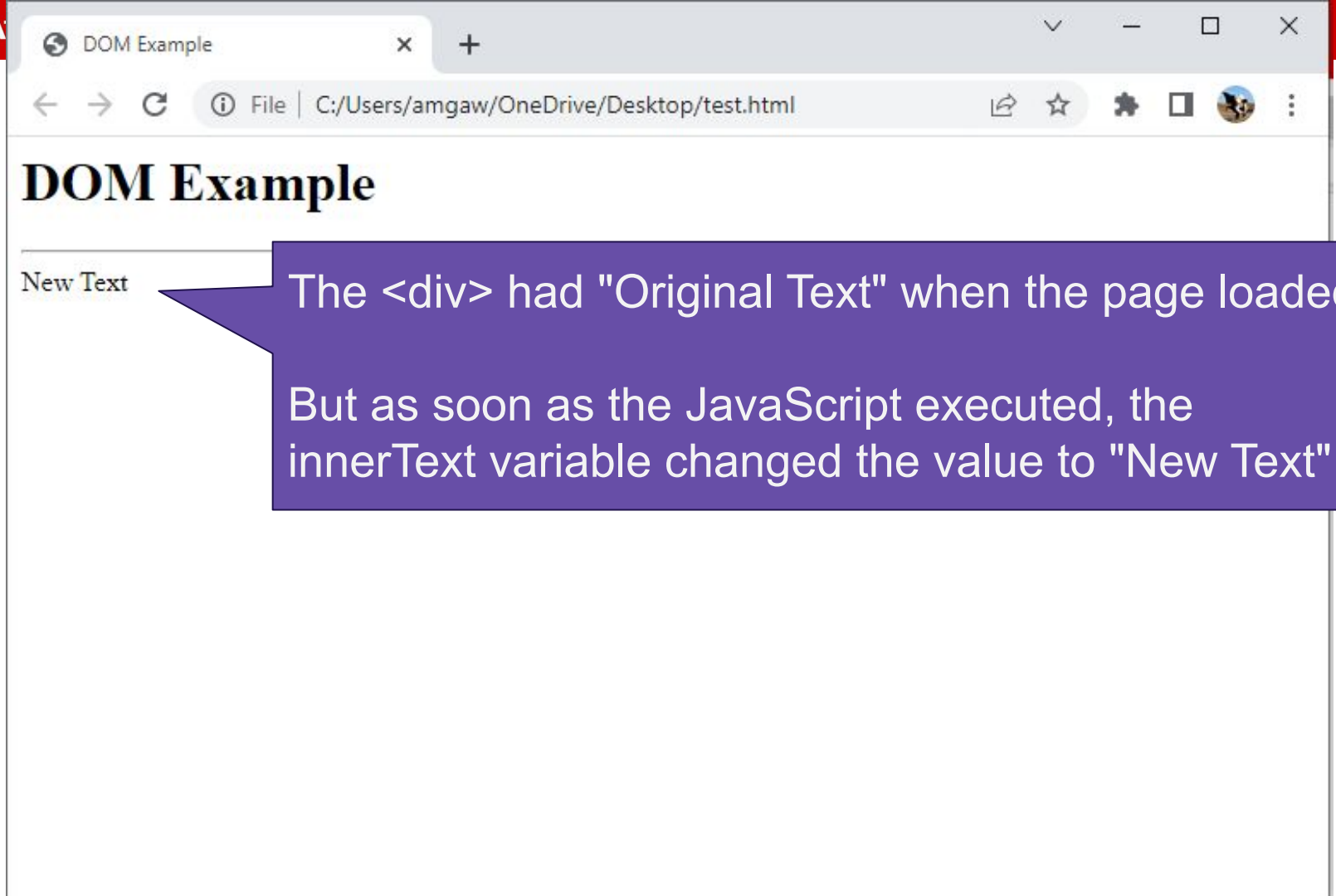
DOM Example

```
<html>
 <head>
   <meta charset="UTF-8">
   <title>DOM Example</title>
 </head>
 <body>
  <h1>DOM Example</h1>
  <hr>
  <div id='insert_here'>Original Text</div>
 </body>
 <script>
   document.getElementById('insert_here').innerText = "New Text";
 </script>
</html>
```

HTML is first rendered...

THEN JavaScript is executed

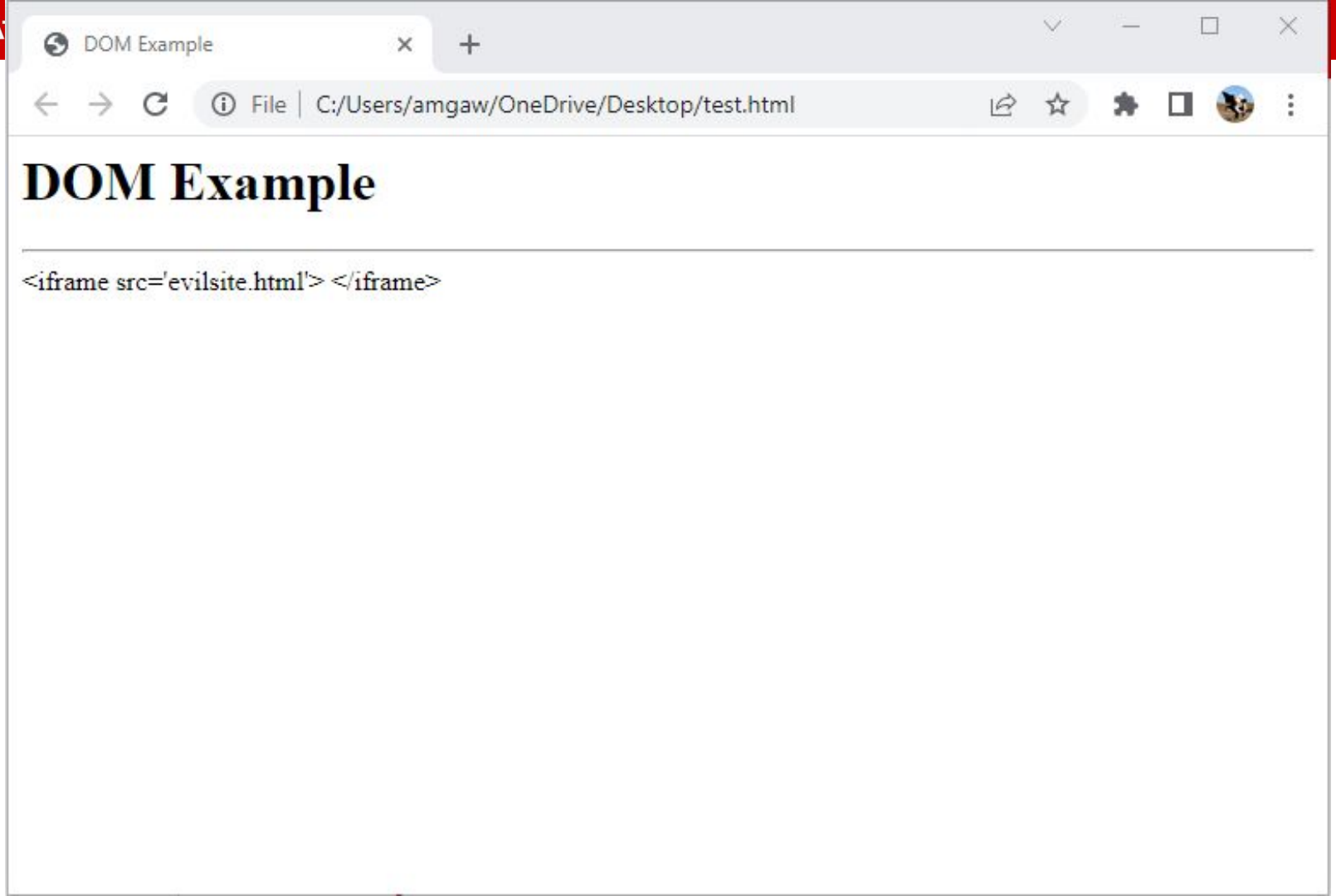

DOM Example
File | C:/Users/amgaw/OneDrive/Desktop/test.html
DOM Example
New Text


DOM Example
File | C:/Users/amgaw/OneDrive/Desktop/test.html
DOM Example
New Text
The had "Original Text" when the page loaded.
But as soon as the JavaScript executed, the innerText variable changed the value to "New Text"

DOM Example

```
<html>
 <head>
   <meta charset="UTF-8">
   <title>DOM Example</title>
 </head>
 <body>
  <h1>DOM Example</h1>
  <hr>
  <div id='insert_here'>Original Text</div>
 </body>
 <script>
   var x = document.getElementById('insert_here');
   x.innerText = "<iframe src='evilsite.html'> </iframe>";
 </script>
</html>
```

We can place **anything** for the browser to render

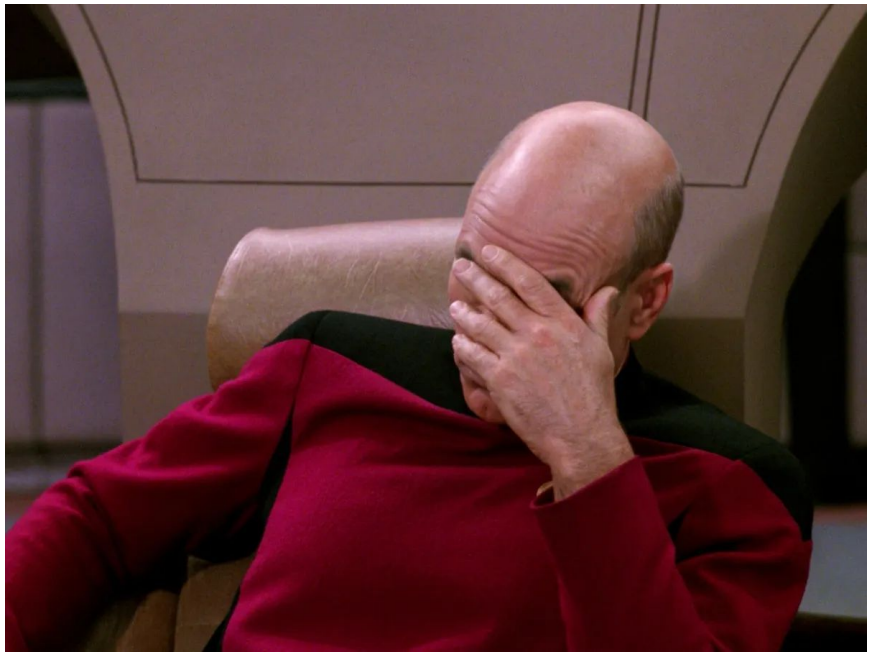

DOM Example
File | C:/Users/amgaw/OneDrive/Desktop/test.html
DOM Example
<iframe src='evilsite.html'> </iframe>

DOM Example

File | C:/Users/amgaw/OneDrive/Desktop/test.html

DOM Example

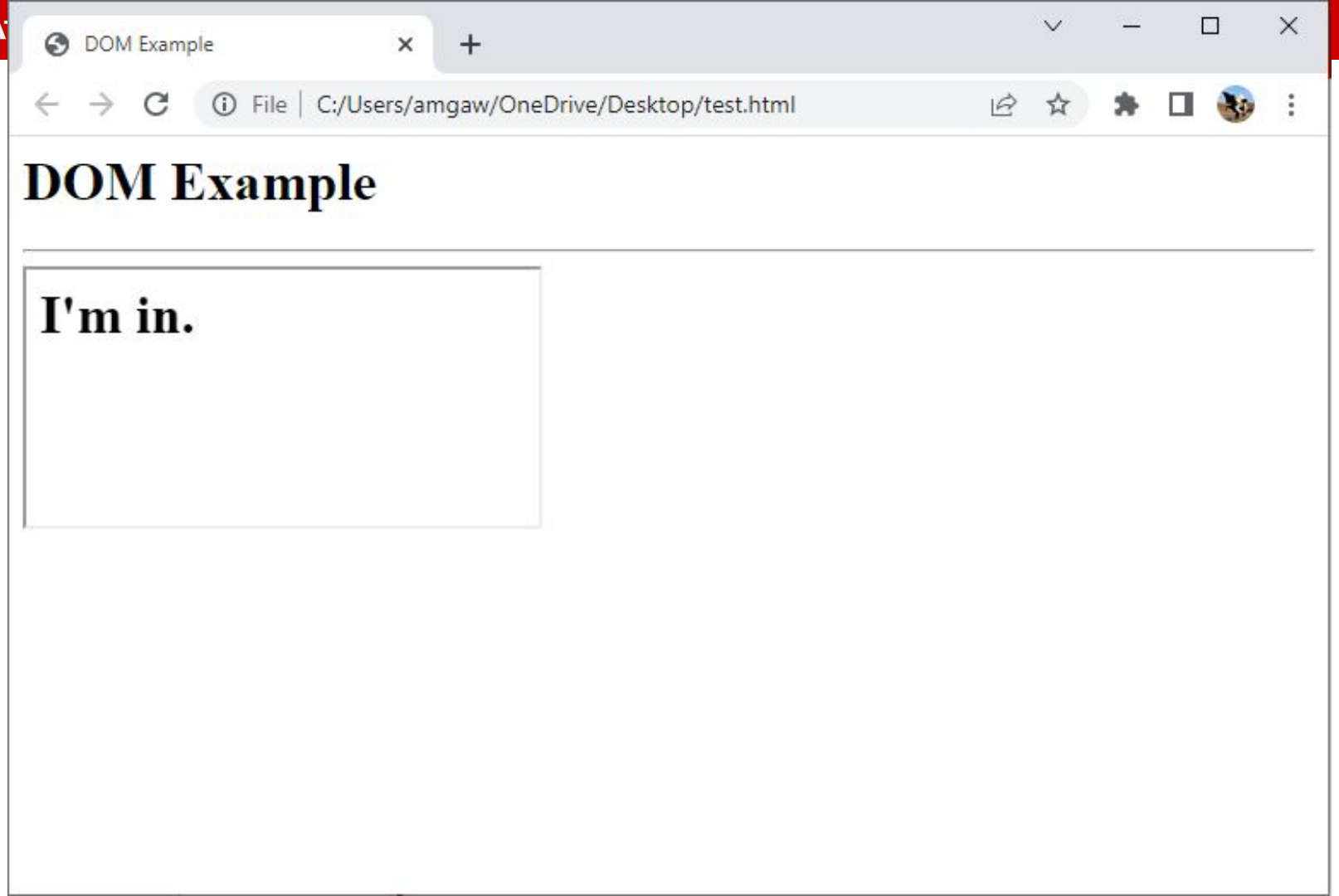
<iframe src='evilsite.html'> </iframe>

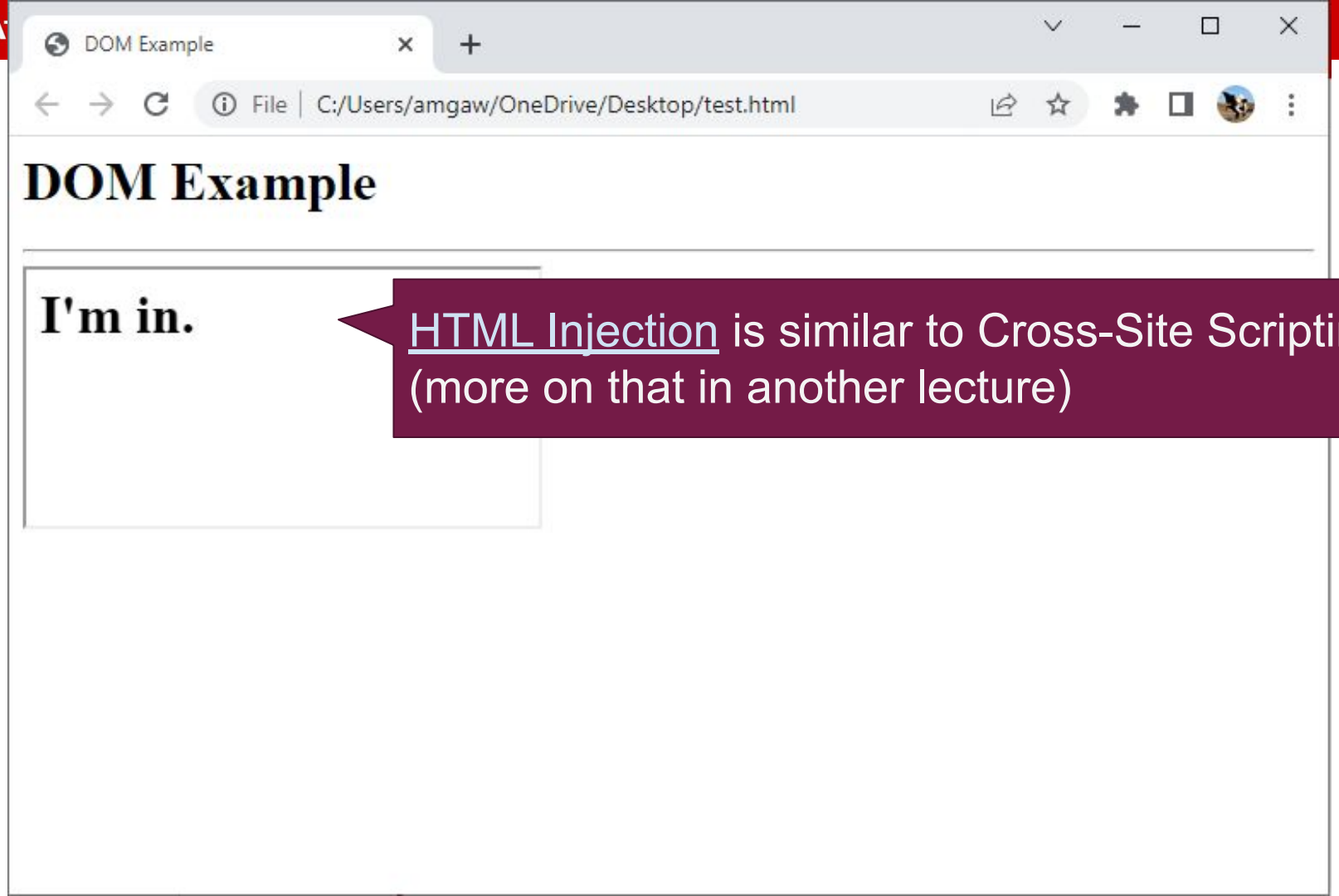


DOM Example

```
<html>
 <head>
   <meta charset="UTF-8">
   <title>DOM Example</title>
 </head>
 <body>
  <h1>DOM Example</h1>
  <hr>
  <div id='insert_here'>Original Text</div>
 </body>
 <script>
   var x = document.getElementById('insert_here');
   x.innerHTML = "<iframe src='evilsite.html'> </iframe>";
 </script>
</html>
```

But it does need to render...


DOM Example
File | C:/Users/amgaw/OneDrive/Desktop/test.html
DOM Example
I'm in.


DOM Example
File | C:/Users/amgaw/OneDrive/Desktop/test.html
DOM Example
I'm in.
HTML Injection is similar to Cross-Site Scripting (more on that in another lecture)

Preventing HTML Injection

- **NEVER** let raw user input be rendered
- Escape HTML special characters to **&equivalent;**

```php
<?php
$user_input = "<iframe src='evilsite.html'>";
$parse = htmlspecialchars($user_input);
// converts to &lt;iframe src=&#039;evilsite.html&#039;&gt;
?>
```

PHP

Converts **<** to **<** so when it is displayed it renders as text instead of legitimate HTML

```python
desc = request.form.get("description")
desc = html.escape(desc, True) # Convert HTML entities to Unicode
```

Python

Using the DOM

- Coding proper DOM access in a cross-browser world is a **nightmare**

- Some highlights from http://stackoverflow.com/questions/565641/what-cross-browser-issues-have-you-faced
  - **Internet Explorer** does not replace **` `** or HTML char code **`160`**, you need to replace it w/ its Unicode equivalent **`\u00a0`**
  - In **Firefox**, a dynamically created input field inside a form (created using **`document.createElement`**) does not pass its value on form submission
  - **`document.getElementById`** in **Internet Explorer** will return an element even if the **`name`** attribute matches.
    - **Mozilla** only returns element if **`id`** matches

Browser Object Model (BOM)

- Programmatic interface to everything outside the document (aka the browser)
- No complete standard

- Examples

```
window.name = "New name"
window.close()
window.location = "http://example.com"
```

JavaScript vs. DOM and BOM

- JavaScript the language is defined separate from the DOM and BOM
  - DOM has its own specification, and much of the BOM is specified in HTML5 spec
- In the web context, these are often confused, because they are used together so often
- However, with JavaScript appearing everywhere, it's an important distinction
  - Server-side code using Node.js
  - Database queries (MongoDB)
  - Flash (dated has its own DOM-like capabilities)
  - Java applications (javax.script)
  - Windows applications (WinRT)

JavaScript – Object-based

- Almost everything in JavaScript is an object
  - Objects are associative arrays (hash tables), and the properties and values can be added and deleted at run-time

```
var object = {test: "foo", num: 50};
object['foo'] = object;
console.log(object[object['test']]);
object.num = 1000;
console.log(object['num']);
```

```
> var object = {test: "foo", num: 50};
< undefined
> object['foo'] = object;
< ▼ Object {test: "foo", num: 50, foo: Object} i
    ▶ foo: Object
      num: 1000
      test: "foo"
    ▶ __proto__: Object
> console.log(object[object['test']]);
  ▶ Object {test: "foo", num: 50, foo: Object}
< undefined
> object.num = 1000;
< 1000
> console.log(object['num']);
  1000
< undefined
>
```

JavaScript – Anonymous Functions and Closures

```
var createFunction = function() {
    var count = 0;
    return function () {
        return ++count;
    };
};
var inc = createFunction();
inc();
inc();
inc();
var inc2 = createFunction();
inc2();
...
```

```
> var createFunction = function() {
      var count = 0;
      return function () {
          return ++count;
      };
  };
< undefined
> var inc = createFunction();
< undefined
> inc();
< 1
> inc();
< 2
> inc();
< 3
> var inc2 = createFunction();
< undefined
> inc2();
< 1
>
```

JavaScript – Runtime Evaluation

- JavaScript contains features to interpret a string as code and execute it
  - eval
  - Function
  - setTimeout
  - setInterval
  - execScript (deprecated since IE11)

```
var foo = "bar";
eval("foo = 'admin';");
console.log(foo);
var x = "console.log('hello');";
var test = new Function(x);
test();
```

```
> var foo = "bar";
< undefined
> eval("foo = 'admin';");
< "admin"
> console.log(foo);
  admin                                          VM49:1
< undefined
> var x = "console.log('hello');";
< undefined
> var test = new Function(x);
< undefined
> test()
  hello                                          VM54:2
< undefined
>
```

JavaScript Uses – Form Validation

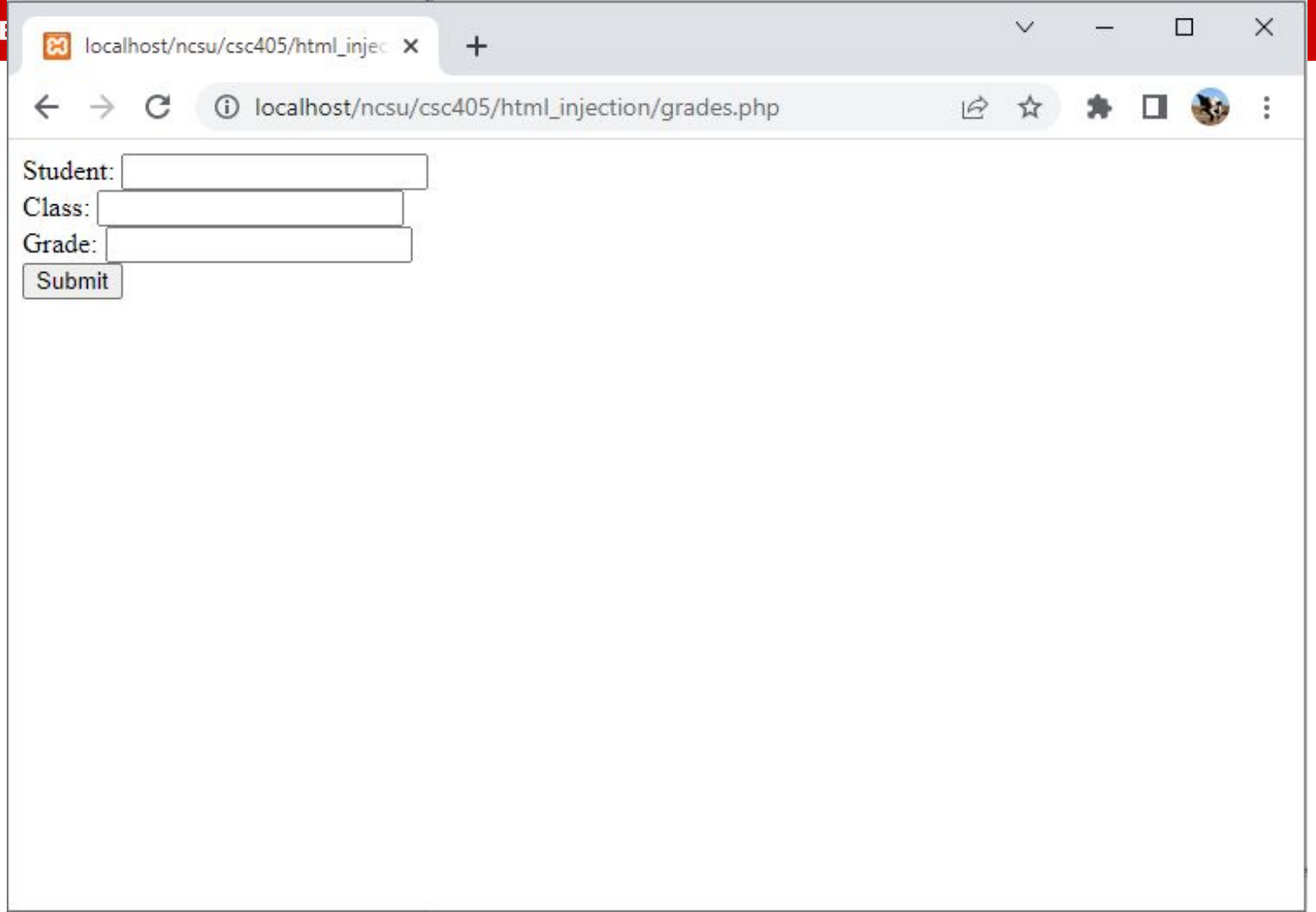
- How to validate user input on HTML forms?
- Traditionally requires a round-trip to the server, where the server checks if the input is valid

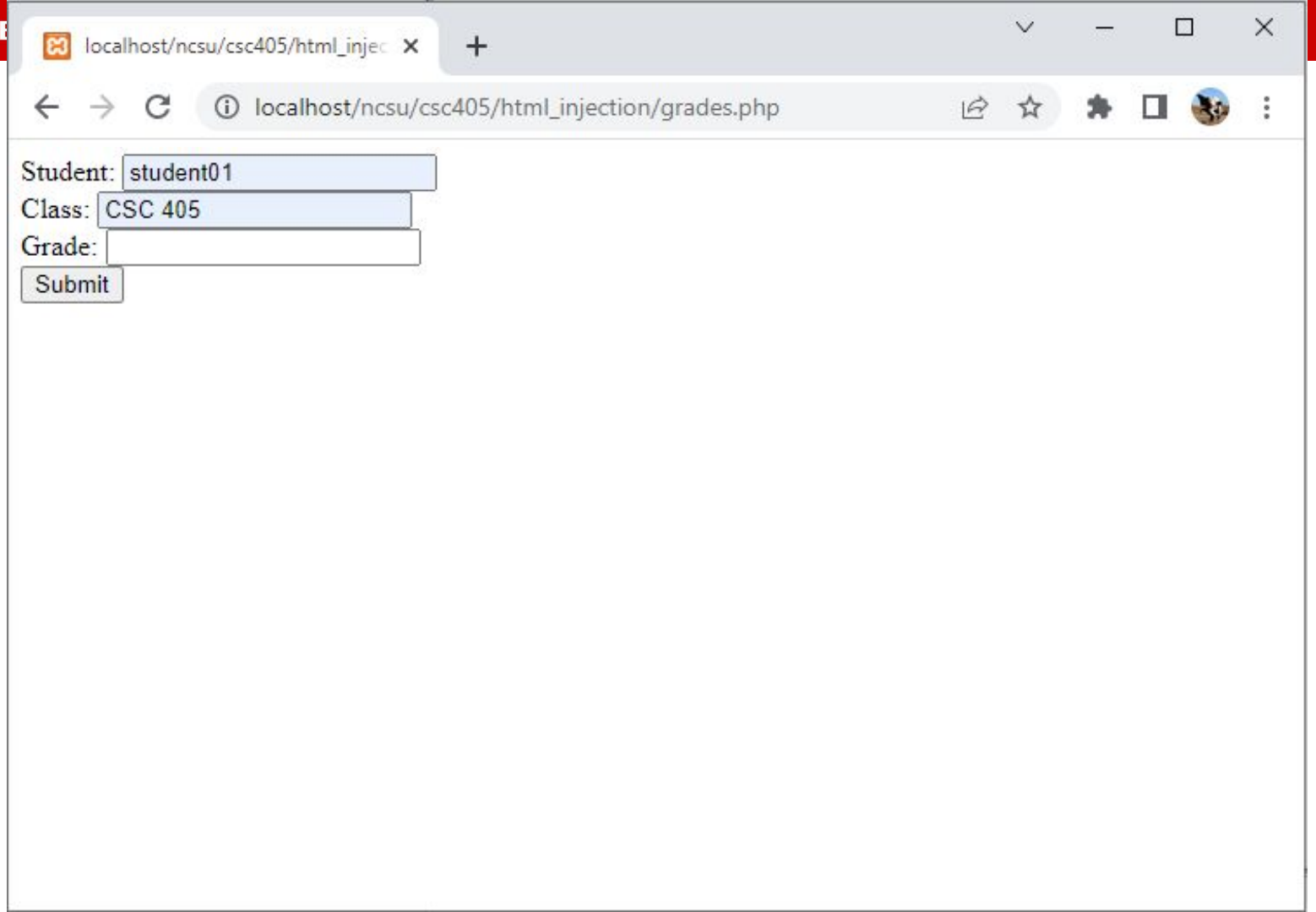
JavaScript Uses – Form Validation

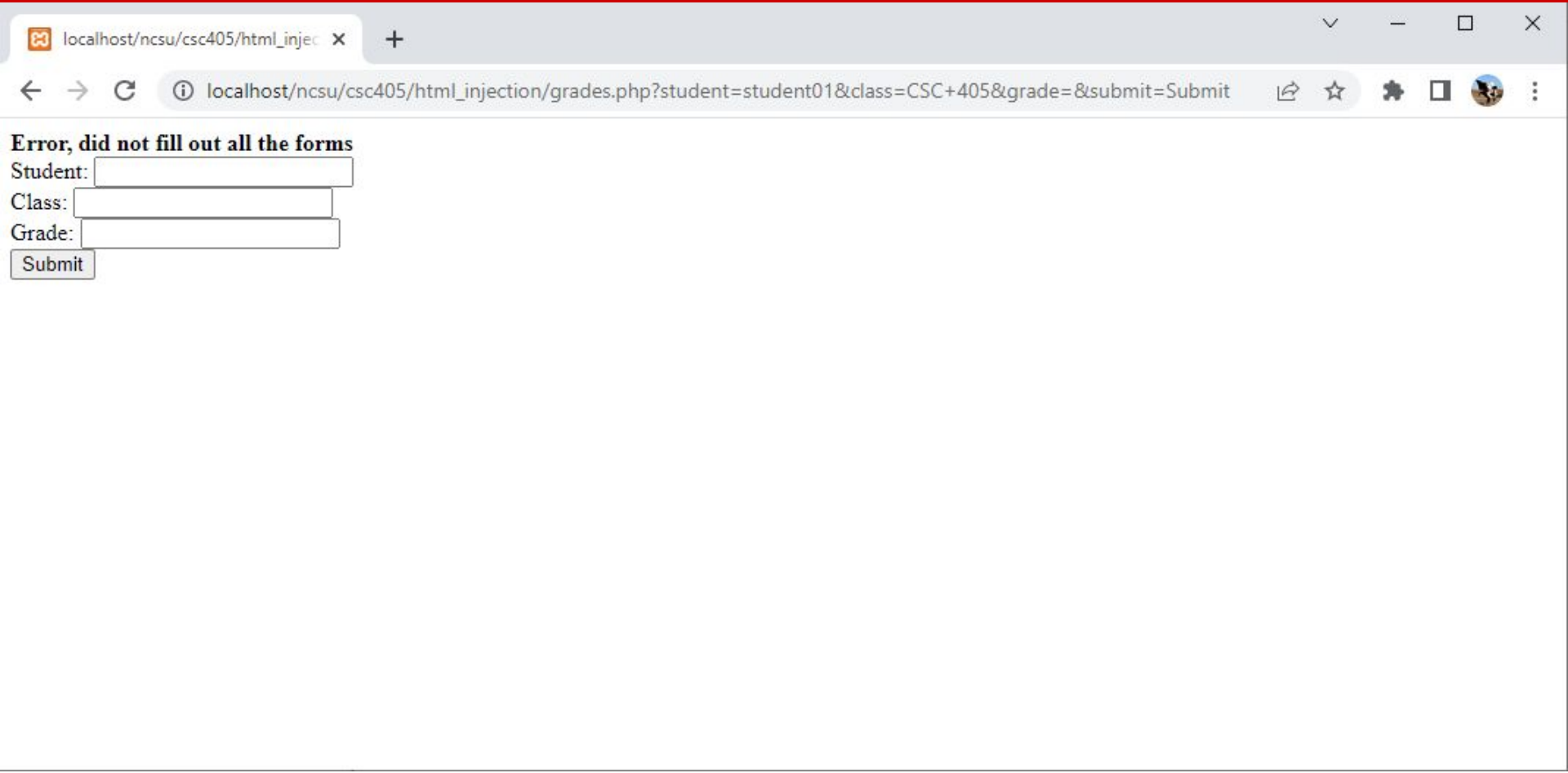
```
<?php
if ($_GET['submit']) {
  $student = $_GET['student'];
  $class = $_GET['class'];
  $grade = $_GET['grade'];
  if (empty($student) || empty($class) || empty($grade)) {
        echo "<b>Error, did not fill out all the forms</b>";
  }
  else if (!($grade == 'A' || $grade == 'B' || $grade == 'C' ||
              $grade == 'D' || $grade == 'F')) {
        echo "<b>Error, grade must be one of A, B, C, D, or F</b>";
  }
  else { echo "<b>Grade successfully submitted!</b>";
  }
} ?>
<form>
 Student: <input type="text" name="student"><br>
 Class:  <input type="text" name="class"><br>
 Grade:  <input type="text" name="grade"><br>
 <input type="submit" name="submit">
</form>
```

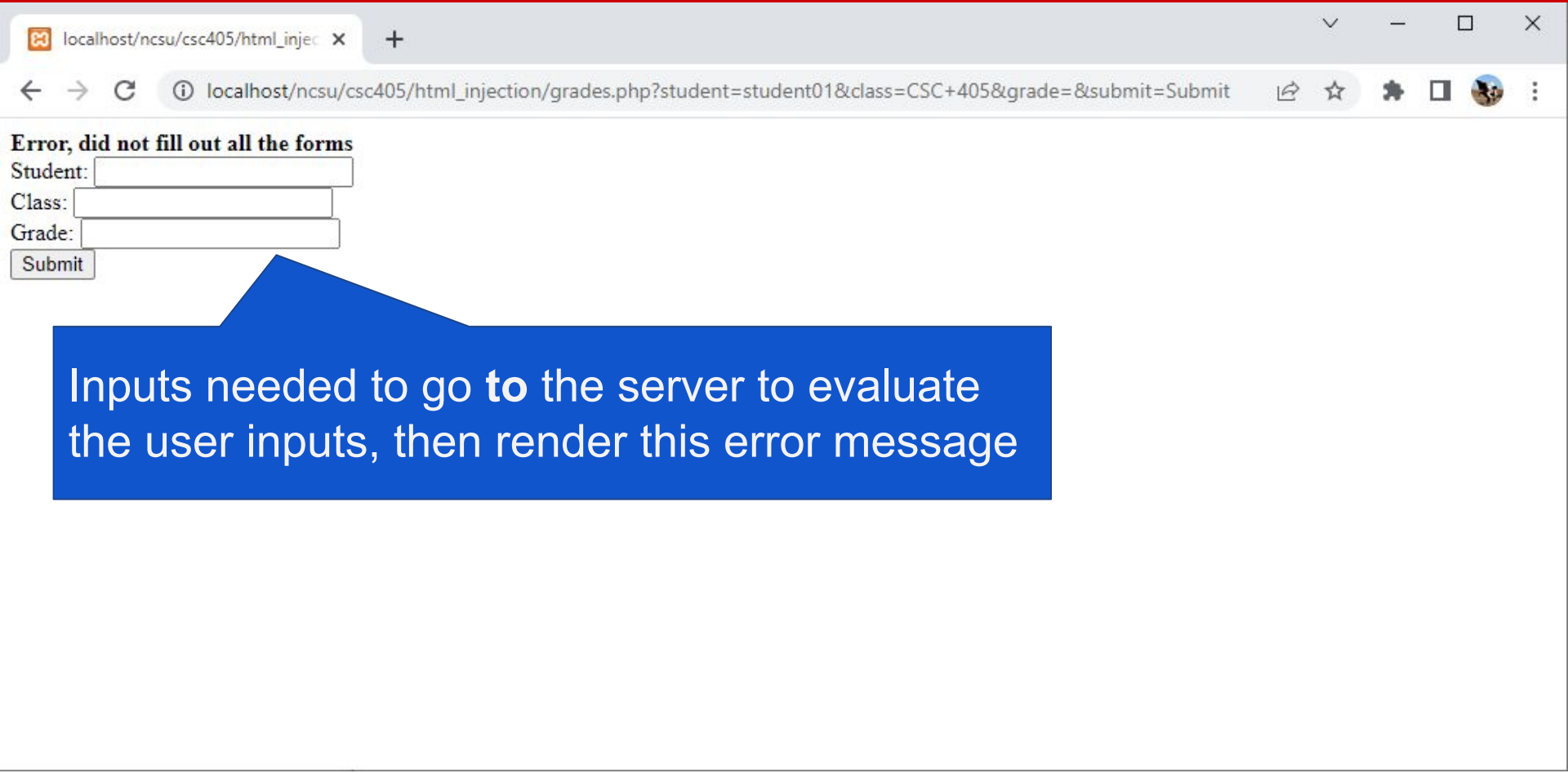
Note about PHP

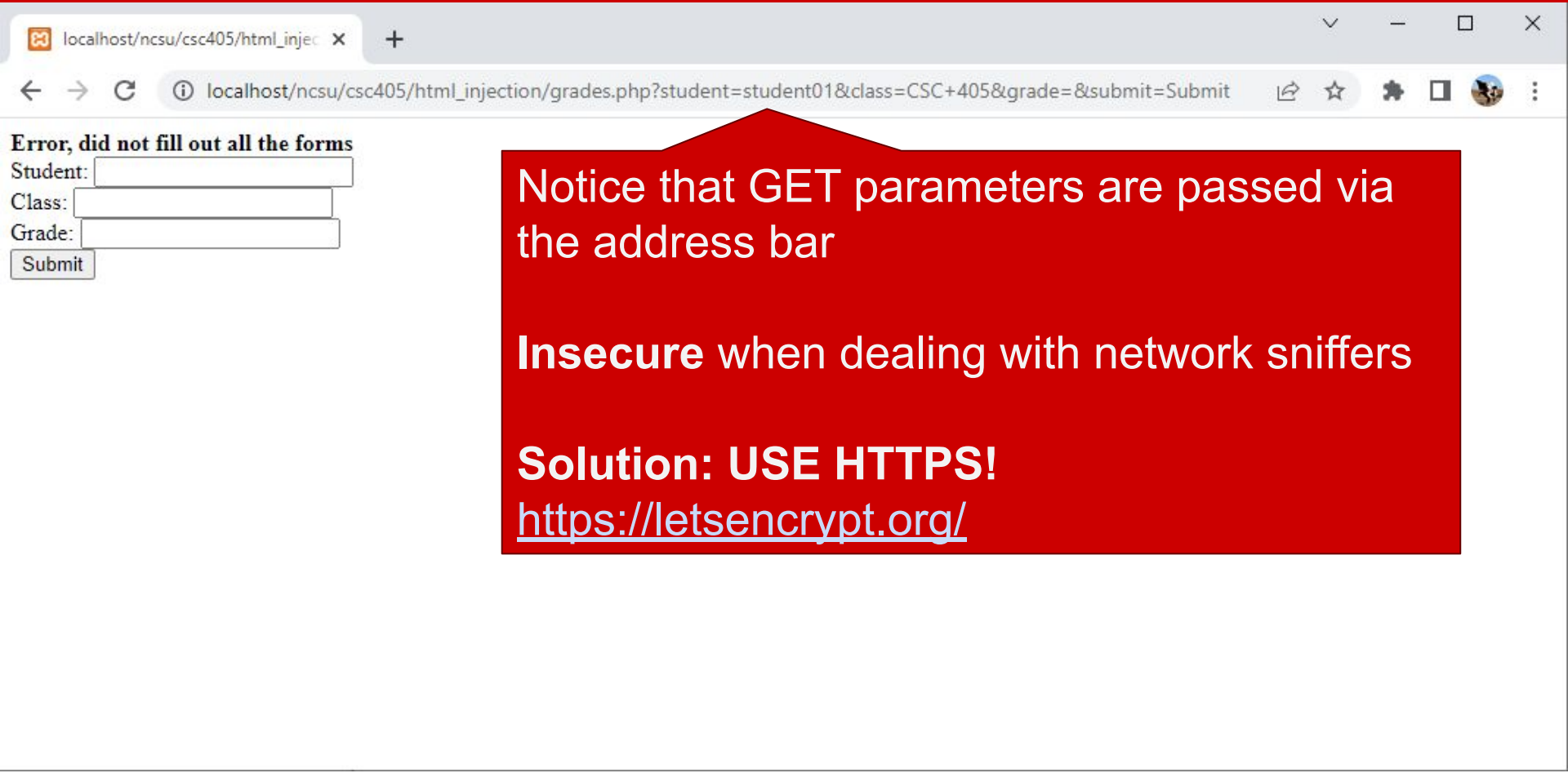
```php
<?php
$string = 'cup';
$name = 'coffee';

$str = 'This is a $string with my $name in it.<br>';
echo $str;
// Outputs: This is a $string with my $name in it.

eval("\$str = \"$str\";");
echo $str;
// Outputs: This is a cup with my coffee in it.
?>
```


localhost/ncsu/csc405/html_injec
localhost/ncsu/csc405/html_injection/grades.php
Student:
Class:
Grade:
Submit


localhost/ncsu/csc405/html_injec
localhost/ncsu/csc405/html_injection/grades.php
Student: student01
Class: CSC 405
Grade:
Submit


localhost/ncsu/csc405/html_inje
localhost/ncsu/csc405/html_injection/grades.php?student=student01&class=CSC+405&grade=&submit=Submit
Error, did not fill out all the forms
Student:
Class:
Grade:
Submit

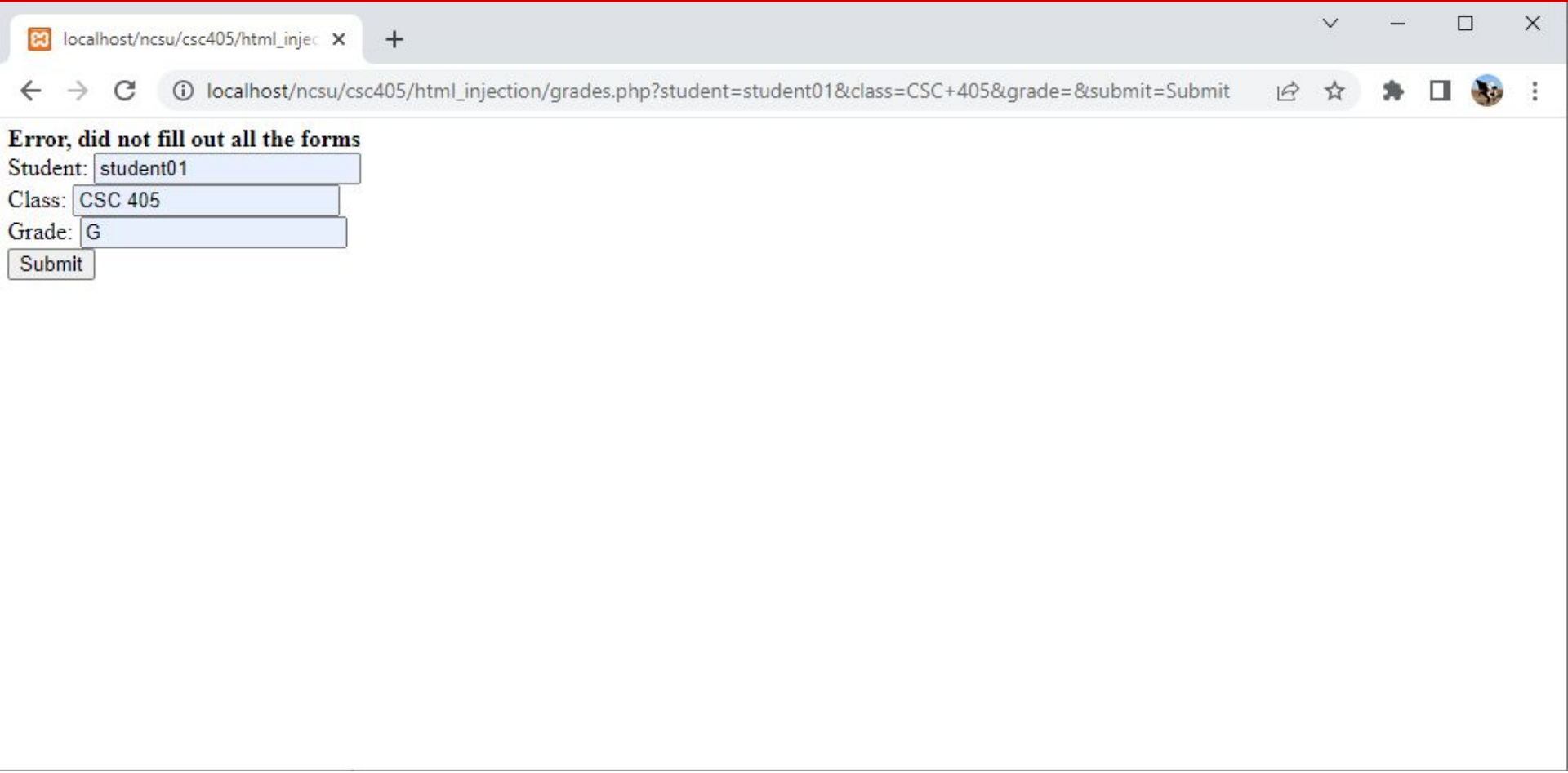

localhost/ncsu/csc405/html_inje
localhost/ncsu/csc405/html_injection/grades.php?student=student01&class=CSC+405&grade=&submit=Submit
Error, did not fill out all the forms
Student:
Class:
Grade:
Submit
Inputs needed to go **to** the server to evaluate the user inputs, then render this error message



Notice that GET parameters are passed via the address bar

Insecure when dealing with network sniffers

Solution: USE HTTPS!
https://letsencrypt.org/


localhost/ncsu/csc405/html_injec
localhost/ncsu/csc405/html_injection/grades.php?student=student01&class=CSC+405&grade=&submit=Submit
Error, did not fill out all the forms
Student: student01
Class: CSC 405
Grade: G
Submit


localhost/ncsu/csc405/html_inje
localhost/ncsu/csc405/html_injection/grades.php?student=s
Error, grade must be one of A, B, C, D, or F
Student:
Class:
Grade:
Submit


localhost/ncsu/csc405/html_inje
localhost/ncsu/csc405/html_injection/grades.php?student=s
Error, grade must be one of A, B, C, D, or F
Student: student01
Class: CSC 405
Grade: A
Submit

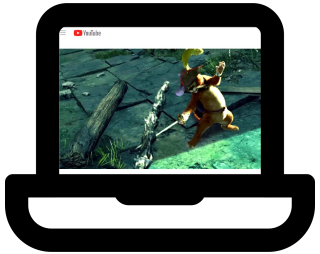
Grade successfully submitted!

Student:

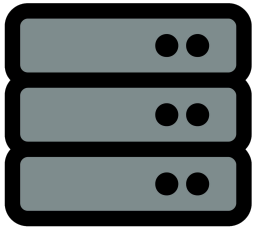
Class:

Grade:

Submit



grades.php



empty class field

wrong grade format

correct submission

JavaScript Uses – Form Validation

- How to validate user input on HTML forms?
- Traditionally requires a round-trip to the server, where the server can check the input to make sure that it is valid
  - But we can also do it **client-side**

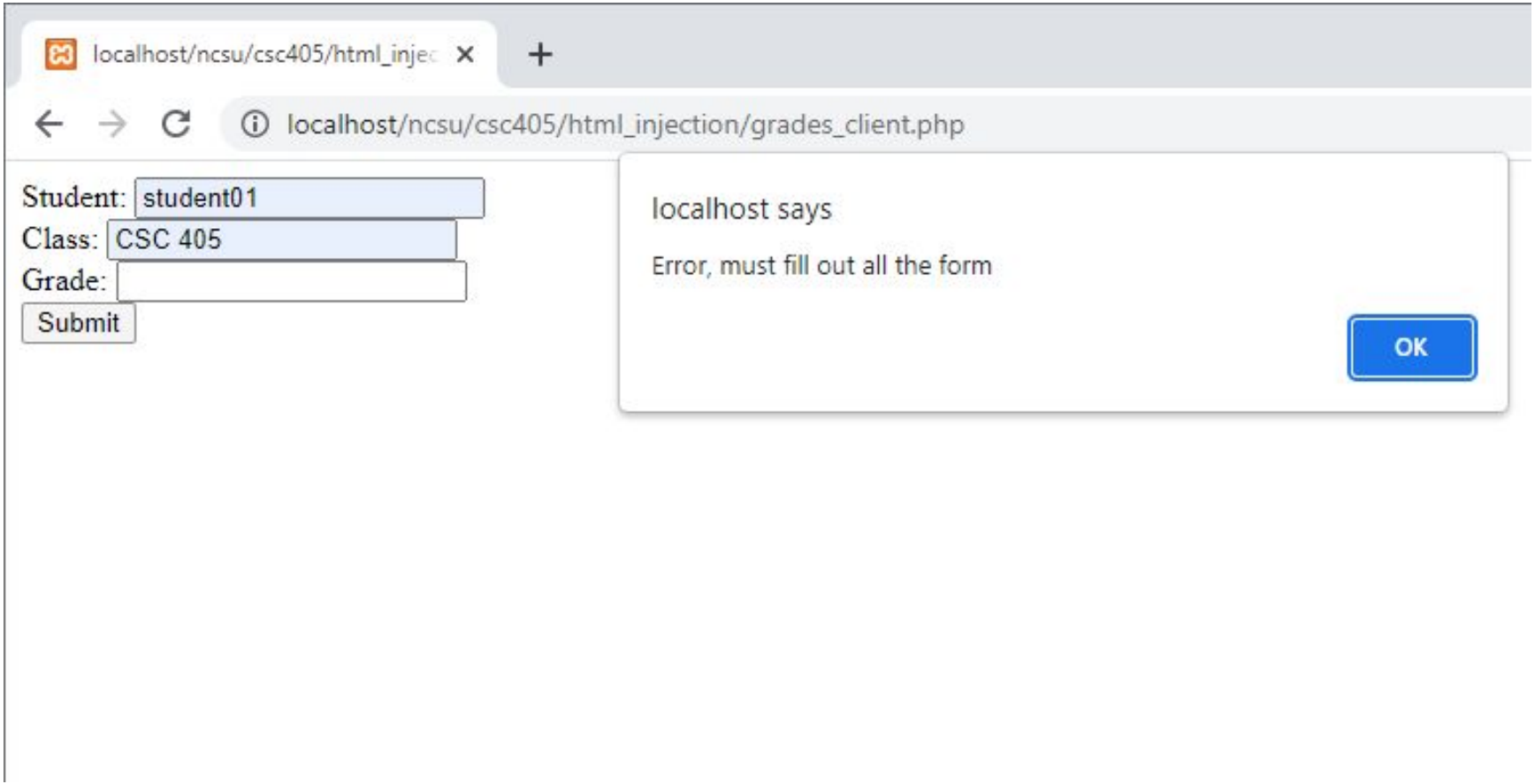
JavaScript Uses – Form Validation

```
<script>
function check_form() {
  var form = document.getElementById("the_form");
  if (form.student.value == "" || form.class.value == "" || form["grade"].value == ""){
        alert("Error, must fill out all the form");
        return false;
  }
  var grade = form["grade"].value;
  if (!(grade == 'A' || grade == 'B' || grade == 'C' ||
        grade == 'D' || grade == 'F')) {
        alert("Error, grade must be one of A, B, C, D, or F");
        return false;
  }
  return true;
}
</script>
<form id="the_form" onsubmit="return check_form()">
 Student: <input type="text" name="student"><br>
 Class:  <input type="text" name="class"><br>
 Grade:  <input type="text" name="grade"><br>
 <input type="submit" name="submit">
</form>
```

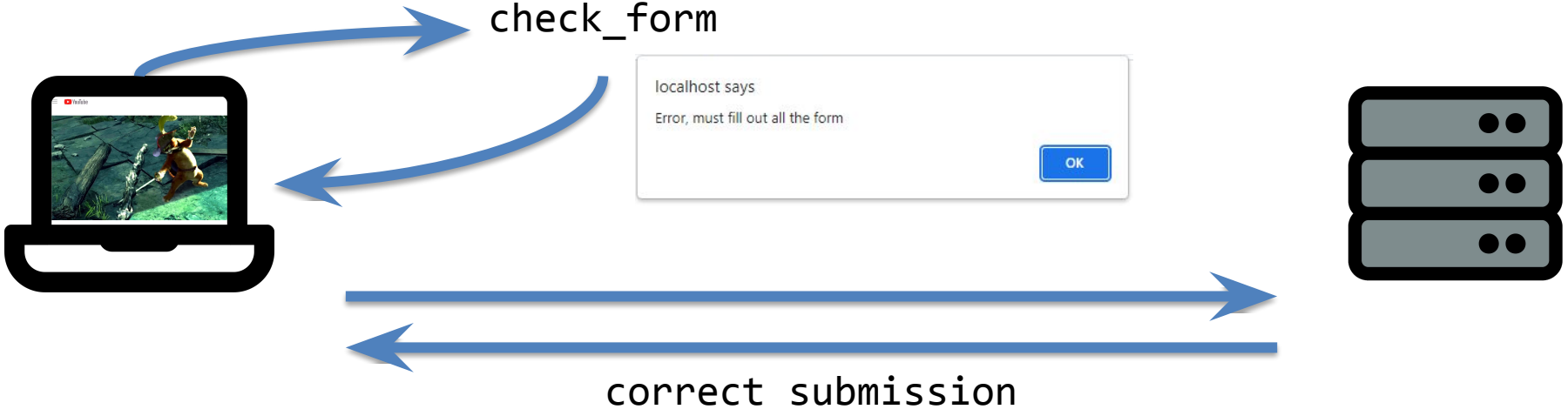
JavaScript Uses – Form Validation

```
<script>
function check_form() {
  var form = document.getElementById("the_form");
  if (form.student.value == "" || form.class.value == "" || form["grade"].value == ""){
        alert("Error, must fill out all the form");
        return false;
  }
  var grade = form["grade"].value;
  if (!(grade == 'A' || grade == 'B' || grade == 'C' ||
        grade == 'D' || grade == 'F')) {
        alert("Error, grade must be one of A, B, C, D, or F");
        return false;
  }
  return true;
}
</script>
<form id="the_form" onsubmit="return check_form()">
 Student: <input type="text" name="student"><br>
 Class:  <input type="text" name="class"><br>
 Grade:  <input type="text" name="grade"><br>
 <input type="submit" name="submit">
</form>
```

Clicking **`Submit`** triggers **`check_form`** and only if it returns **true** do we send the data to the server


localhost/ncsu/csc405/html_inje
localhost/ncsu/csc405/html_injection/grades_client.php
Student: student01
Class: CSC 405
Grade:
Submit
localhost says
Error, must fill out all the form
OK

grades_client.php



Client-Side Validation

- Now that we're doing validation on the client, can we get rid of all those checks in our server-side code?
  - No!
  - No guarantee that client-side validation is performed
    - User disables JavaScript
    - Command-line clients

Source: https://github.com/OWASP/CheatSheetSeries/blob/master/cheatsheets/AJAX_Security_Cheat_Sheet.md

Client-Side Validation

- Now that we're doing validation on the client, can we get rid of all those checks in our server-side code?
  - No!
  - No guarantee that client-side validation is performed
    - User disables JavaScript
    - Command-line clients
- Users could enter arbitrary data that does not conform to your validation
  - Could lead to a security compromise or not

Source: https://github.com/OWASP/CheatSheetSeries/blob/master/cheatsheets/AJAX_Security_Cheat_Sheet.md

Client-Side Validation

- Now that we're doing validation on the client, can we get rid of all those checks in our server-side code?
  - No!
  - No guarantee that client-side validation is performed
    - User disables JavaScript
    - Command-line clients
- Users could enter arbitrary data that does not conform to your validation
  - Could lead to a security compromise or not
- So the validation must remain on the server-side and the client-side
  - Brings up another problem, how to perform consistent validation when server-side and client-side written in different languages

Source: https://github.com/OWASP/CheatSheetSeries/blob/master/cheatsheets/AJAX_Security_Cheat_Sheet.md

WASM: WebAssembly

- What if we join the 1st half of this class to the 2nd half
  - Stack based execution model
  - Pre-compiled, instructions
  - You can read it in text form: WebAssembly Text (WAT)
- WASM decompilation is harder. You can compile Rust, C, C++, and more to WASM
- Доверя́й, но проверя́й: SFI safety for native-compiled Wasm
- More complexity to the browser = more of an attack surface
  - Security Zen: Claude found a CVE in Firefox by exploiting how WASM bindings work in JavaScript