Object Collections

Object-oriented programming is most powerful when it is being used to break up a complex application into many smaller components. Often, we would find it useful to consider many of the components in an application to be members of a collection: in an email application, one part of the screen shows a list of emails; an application's toolbar contains a set of tools; a table in a web page contains a number of rows, each of which has a number of cells in it. In all of these cases (and many more), it is operationally helpful to consider the whole collection (emails, tools, table rows and cells) as a component. It lets us deal with aggregates in a way that is common in real life – you have a collection of photos, music tracks, textbooks, and for most people, it is easier to keep these organised in a photo album (ok – probably an online one), iPod and bookshelf.

Javascript Aggregation

Javascript gives us a few ways to group individual objects into a single object t make a collection:

- Arrays: an array is normally organised as an indexed list of similar types of object. The index is an integer, in the range 0 to 1 less than the number of elements in the array
- Objects: an object, as we saw in the previous chapter, is simply a group of name + value pairs. We can use this to create a ***mapping***, which is a collection of objects (the values) that are associated with a collection of ***keys*** (typically strings)

Custom Objects: we can create objects which have methods added specifically to manage collections of other objects. This gives us the opportunity to improve how Javascript deals with collections in some way – added security, easier access, aggregated objects sorted in some way or other specialized object-management features

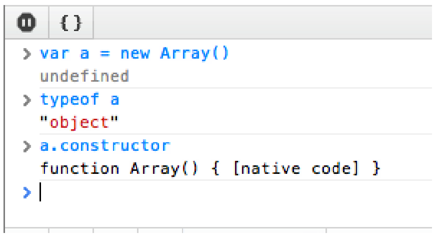
Arrays and Object mappings are built in to the Javascript language, and so these would be the default approaches we would use to forming collections. However, the option of creating a customized collection is often a powerful one that we should consider.

Javascript Arrays

An array is a group of objects organized by an index number. JS gives us two ways to create an array:

1. var a = new Array();
2. var a = [];

Both of these methods are equivalent. What version 1 shows is that a JS array is just another type of object. Array() is the constructor function and methods associated with this constructor apply to any array. If you were to create an array in this way and then query it in a Console window, you would get the following results:



```
> var a = new Array()
  undefined
> typeof a
  "object"
> a.constructor
  function Array() { [native code] }
> |
```

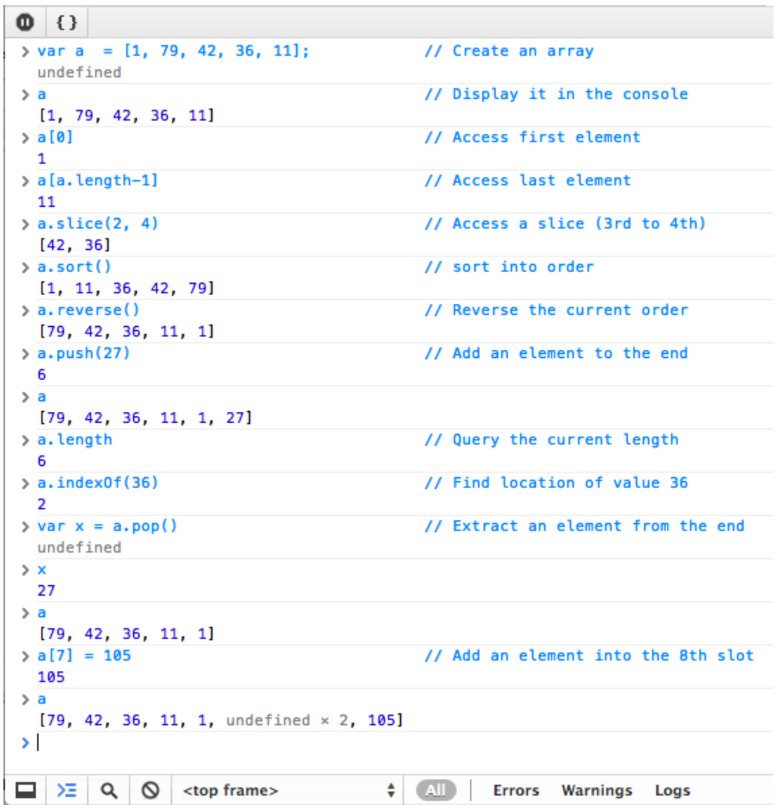
Figure 4.1: Querying an array object in a console window.

The second method is normally to be preferred. This is because it is always possible for someone (maybe you, more likely someone who has created code for or added code to an application) to re-define how the Array() constructor works, and here be dragons. Given the right set of circumstances, every item you add to an array using some unknown constructor could just be getting sent back to scamming site: imagine the consequences if you were adding BankAccount passwords to the array.

It is not possible to subvert the [] method for declaring an array (at least, not within JS code), and so this method is much safer. If we wanted to create an array containing 4 integers, we would use:

```
var a  = [1, 79, 42, 36, 11];
```

Now, using the standard indexing, we can access any element of the array and apply array methods to it:



```
> var a  = [1, 79, 42, 36, 11];            // Create an array
  undefined
> a                                        // Display it in the console
  [1, 79, 42, 36, 11]
> a[0]                                     // Access first element
  1
> a[a.length-1]                            // Access last element
  11
> a.slice(2, 4)                            // Access a slice (3rd to 4th)
  [42, 36]
> a.sort()                                 // sort into order
  [1, 11, 36, 42, 79]
> a.reverse()                              // Reverse the current order
  [79, 42, 36, 11, 1]
> a.push(27)                               // Add an element to the end
  6
> a
  [79, 42, 36, 11, 1, 27]
> a.length                                 // Query the current length
  6
> a.indexOf(36)                            // Find location of value 36
  2
> var x = a.pop()                          // Extract an element from the end
  undefined
> x
  27
> a
  [79, 42, 36, 11, 1]
> a[7] = 105                               // Add an element into the 8th slot
  105
> a
  [79, 42, 36, 11, 1, undefined × 2, 105]
> |
```

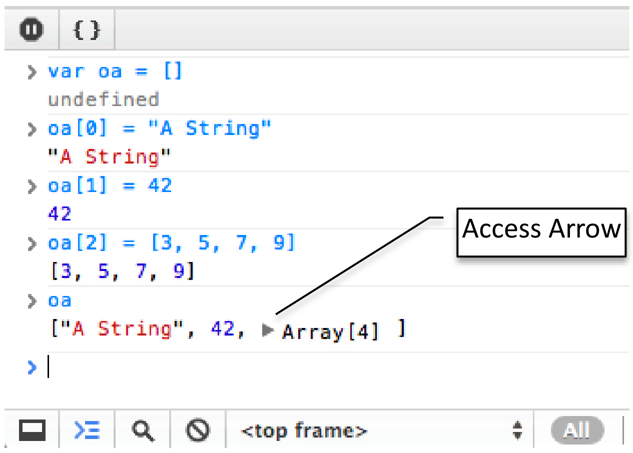
Figure 4.2: An array in the Console

Figure 4.2 shows an array being created and manipulated in the Chrome Console. I've added comments to indicate what each operation is doing with the array, so it should be fairly clear what is happening. In addition to creating the array and accessing individual elements:

- the **length** property has been used to get the index of the last element (it is one less than length)
- the **slice()** method is used to extract a sequence of elements (starting at index to and going up to, but not including, index 4)
- the **sort()** method has been used to sort it into ascending numerical order
- the **reverse()** method has reversed the order of all of the elements in the array
- the **push()** method adds a new element to the end of the array, and returns the new length
- the **indexOf()** method finds an element and returns its position in the array (or -1 if it does not find it)

- the **pop()** method removes the last element of the array and returns it
- adding an element directly to a specific index, e.g. **a[7] = 105**, inserts the element at the given location, and extends the array up to this location if it is too short. Added elements up to the inserted one have the value ***undefined***

Note that the array indexes are 0-based. i.e., a[0] is the first element, and a[a.length-1] is the last. JS arrays have several more capabilities, but the most intriguing of them is, JS arrays are polymorphic. i.e. an array does not have to contain objects which are all of the same type. Another way of putting this is that a JS array is an array of Objects, with no restriction on the composition of the objects.



```
> var oa = []
  undefined
> oa[0] = "A String"
  "A String"
> oa[1] = 42
  42
> oa[2] = [3, 5, 7, 9]
  [3, 5, 7, 9]
> oa
  ["A String", 42, ▶ Array[4] ]
> |
```

Figure 4.3: A polymorphic array

In figure 4.3, you can see a String, a Number and another Array being added to an array (oa for Object Array). When asked to report on the contents, the Chrome Console displays the elements appropriately (note that the last element is shown as **Array[4]**, meaning a 4 element array). Click on the access arrow, and the Console will show the composition of the array object.

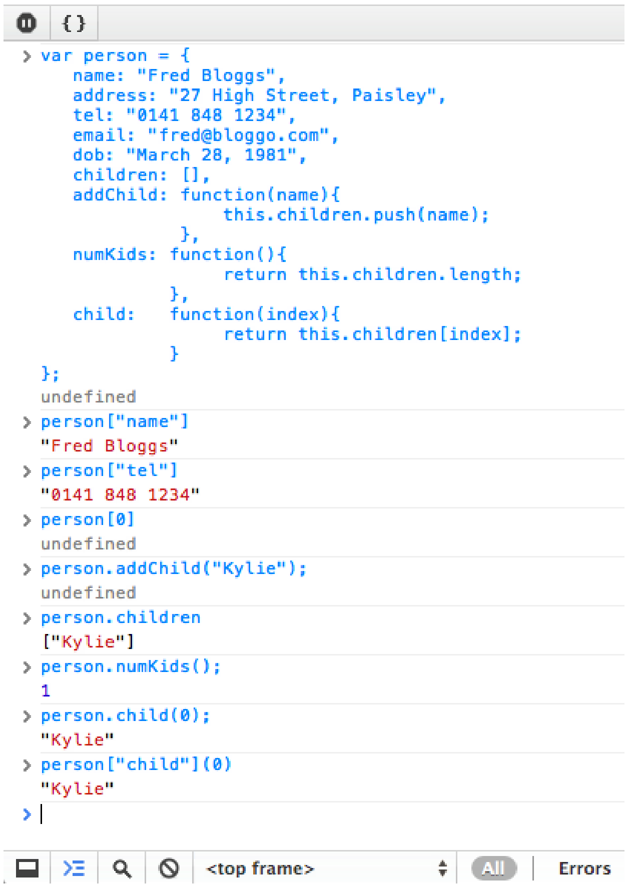
To access an element of the array within the array, simply use a second index in brackets. E.g. **oa[2][1]** is **5**. It would now be possible to add this whole array into another array as an element, meaning that some of the contents would need three indices to access them. We could also add functions to an array as elements.

Given that we can create an array that contains any combination of elements, you might think there is little reason for having the Object type in Javascript. However, Objects have one further trick up their sleeve, in that instead of an index, an element (which is either a property or a method) has a name. It would be quite awkward to use arrays as objects, since you would always need to associate a particular property or method with a number; the code would be difficult to write and to read.

Objects as Mappings (or Maps)

In computing terms, a mapping is a particular way of organising data: in a mapping there is a one-to-one correspondence between a given value (an object), and the key that can be used to access it (usually a String). We say that a value maps to a specific key. The name Associative Array is also used, since a map is like an array except that instead of a numeric index, values are accessed by a key that a programmer typically associates with the object or value being stored.

Javascript Objects are maps, in that each of the properties or methods within an object (all of which are also objects) has a name, which is the key to access that property or method. We can experiment with some literal object notation to demonstrate this:



```
> var person = {
     name: "Fred Bloggs",
     address: "27 High Street, Paisley",
     tel: "0141 848 1234",
     email: "fred@bloggo.com",
     dob: "March 28, 1981",
     children: [],
     addChild: function(name){
                    this.children.push(name);
               },
     numKids: function(){
                    return this.children.length;
              },
     child:   function(index){
                    return this.children[index];
              }
  };
  undefined
> person["name"]
  "Fred Bloggs"
> person["tel"]
  "0141 848 1234"
> person[0]
  undefined
> person.addChild("Kylie");
  undefined
> person.children
  ["Kylie"]
> person.numKids();
  1
> person.child(0);
  "Kylie"
> person["child"](0)
  "Kylie"
> |
```

Figure 4.4: A literal object – querying it as a mapping

In the console session in figure 4.4, you can see a block of statements at the top that defines a person object. The person has a name, address, telephone number, email address, date of birth, and an array of children[]. So far, so object like. It also contains methods to add a child, return the number of children and each individual child.

The code that follows this is almost like the code to access an array, except that instead of integer numbers, the index values are strings inside quote marks. If we try to access an element by number (e.g. person[0]), the console returns *undefined* as its value. Note that we can also use standard object dot notation (e.g. to access the addChild() method, I've used this), and that we can use either syntax for any member (e.g. ***person.child(0)*** is exactly equal to ***person["child"](0)***).

In this example, we're getting some insight into how Javascript manages objects and arrays. An array is simply an object that uses integers for indexes, and an object is simply a map of other objects (which can include functions). One limitation of an object map is that it does not have a length property. If you need to know how many items are it in you need to either keep track of the objects added and removed from it, or count the contents in a **for..in** loop:

```
var count = 0;
for(object in mapping){
    count += 1;
}
```

Listing 4.1: Counting the number of objects in a mapping

Because this is done in a Javascript loop rather than in native code, it is slow to count the number of items in a mapping, and will have to be done every time you need to know the number if it is possible that objects have been added or removed since the last time. For this reason, a true array is a better bet. Alternatively, you could create a custom collection that does this for you.

Custom Collections 1

We can make use of the object/map notation to create clever collections that are able to do useful work with their contents. For example, lets say we're creating a website that allows users to perform statistical calculations on data they enter or upload to the site. It would be sensible to encapsulate this functionality into an object type that dealt with the calculations, leaving us free to develop the appearance of the website and its user-interface without needing to consider how the statistics operate (two different skill-sets, that might be best done by two collaborating programmers – one a Web User-Interface expert and the other a maths wiz. Here's a simple object definition to get the statistics going:

```
/**
 * A constructor and code for an object containing a set of statistical calculations.
 */
var Stats = function(){
   this.values = [];                               // We'll work on an array of numbers.
};

Stats.prototype.insertValue = function(v){
   this.values.push(v);                    // Adding a value to the array
};

Stats.prototype.insertValues = function(vals){
   this.values = this.values.concat(vals);   // Adding an array of values to the array
};

Stats.prototype.getValue = function (index){
    return this.values[index];
};

Stats.prototype.count = function(){
   return this.values.length;                      // How many values?
};

Stats.prototype.average = function(){              // To calculate the average…
   var total = 0, index, max;
   for(index=0, max = this.values.length; index<max; index+=1){
      total += this.values[index];                 // …add all the values together…
   }
   return total / max;                     // …and divide by their number.
};


// Stats object definition – continues over…
```

```
Stats.prototype.variance = function(){
    // The Variance is the average of the squared differences between the values and the
    // mean value.  To calculate this, square the difference between each value and the average
    // value, and add all these squares together.  Finally, divide by the number of values…
    var avg = this.average(), sumDiffsSquared = 0, index, max, d;
    for(index=0, max = this.values.length; index<max; index +=1){
        d = (avg-this.values[index]);
        sumDiffsSquared += d*d;
    }
    return sumDiffsSquared / max;
};

Stats.prototype.standardDeviation = function() {
     //  Standard Deviation is simply the square root of the variance…
     return Math.sqrt(this.variance());
};

// It would be very sensible to test this code on a known set of values.
var testStats = function(){
    var s = new Stats();
    s.insertValues([600, 470, 170, 430, 300]);
    console.log("Second value = " + s.getValue(1));              // Should be 470
    console.log("Count = " + s.count());                         // Should be 5
    console.log("Average = " + s.average());                     // Should be 394
    console.log("Variance = " + s.variance());                   // Should be 21704
    console.log("Standard Deviation = " + s.standardDeviation()); // Should be ~147.3
};

window.onload = testStats;                    // Run the tests when the page loads.
```

Listing 4.1: A definition of a Stats object, which encapsulates some simple statistics

What we have gained from the definition of a statistics class is that we can incorporate statistical calculations on collections of numbers without even remembering how to do it – just include the JS code in a web application, and add a function call or several to insert the numerical collection that we want to analyse into the object. In this respect, we could consider our statistics object to be a set of utility functions, but it works only because of the customized collection we based it around.

We could easily augment the Stats collection object by incorporating functions that let us draw graphs and charts based on the values in it. We'll look into graphics in JS and HTML 5 in a later chapter.

Custom Collections 2

There are certain facilities that can be considered to make a collection class easier to use – being able to access individual elements, being able to find if an element exists in the collection, being able to add, remove one and remove all elements. Programmers with a background in all sorts of languages would expect these facilities to exist in a custom collection. In fact, once we had a collection that provided these features, we could use it as a base for any customised collection – in Javascript we simple need to add functions to the core object. Let's create this base collection, starting with a precise definition of how we expect it to operate:

Property or Method	Example use	Description
Constructor	var c = new Collection()	Constructor for a base collection

add() method	c.add(key, item);
	c.add(key, item, replace);
		1. Add an item and key pair to the collection
		2. Add an item:key pair. If the key exists and

		replace is true, replace the existing item; otherwise don’t
count property	var x = c.count	Find out how many objects are in the collection
exists() method	if(c.exists(“xyz”){ …	Returns true if an object with this key is in the collection already
item() method	var o = item(“xyz”);	Returns an item with the given key, or null if there is no such object
remove() method	c.remove(“xyz”);	Remove an item with the given key
removeAll() method	c.removeAll();	Removes everything from the collection
keys property	var k = c.keys	Returns an array of keys in the collection

Table 4.1: Methods and properties for a core collection class

We’ll base our collection on a mapping.

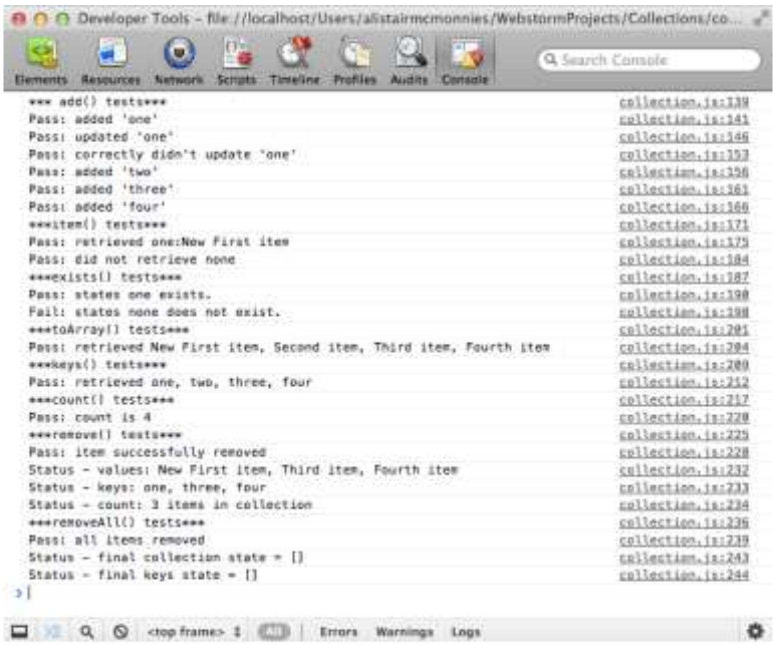
```
/**
 * Collection: an object definition for managing key:value pairs of objects.
 * @constructor Collection: sets up a Collection objects with no items and count == 0
 */
var Collection = function(){
   "use strict";
   this.coll = {};     // Using a map.
   this.length = 0;
};

/**
 * Collection.add() function: adds an item to a collection with a key
 * @param key {Object} - typically a string
 * @param item {Object} - an item to add to the collection
 * @param replace {Boolean} - if true, any existing item with the given key will be replaced
 *                       if false, any existing item with the given key will not be replaced
 * @return {Boolean} - true if the item was added, or if it replaced an existing item
 */
Collection.prototype.add = function(key, item, replace){
   "use strict";
   // If the key exists and we've opted to replace the item, replace it..
   if(this.coll[key] && replace){
      this.coll[key] = item;
      return true;
   }
   // If the key exists, don't replace the item...
   if(this.coll[key]){
      return false;
   } else {    // Add the item and increment count...
      this.coll[key] = item;
      this.length += 1;
      return true;
   }
};

/**
 * Collection.item(key) - returns an item with the given key, or null
 * @param key {Object} - typically a string that uniquely identifies an item
 * @return {*}  - the object at the given key, or null
 */
Collection.prototype.item = function(key){
   "use strict";
   if(this.coll[key]){
      return this.coll[key];
   } else {
      return null;
   }
};

/**
 * Collection.exists(key) - test whether an item is stored uder the given key
 * @param key {Object} - key to test
 * @return {Boolean} - true if an item exists at that key, false otherwise
 */
Collection.prototype.exists = function(key){
   "use strict";
   if(this.coll[key]){
      return true;
   } else {
      return false;
   }
};
```

```
/**
 * Collection.count() - return the number of items in the collection
 * @return {number} - the count of items
 */
Collection.prototype.count = function(){
   "use strict";
   return this.length;
};

/**
 * Collection.remove(key) - remove the item with the given key
 * @param key - the key for the item to remove
 * @return {number} - the new length of the collection
 */
Collection.prototype.remove = function(key){
   "use strict";
   if(this.exists(key)){
      delete this.coll[key];
      this.length -= 1;
   }
   return this.length;
};

/**
 * Collection.removeAll() - deletes all collection contents and sets length to 0.
 */
Collection.prototype.removeAll = function(){
   "use strict";
   this.coll = {};
   this.length = 0;
};

/**
 * Collection.toArray() - return a standard array of the collection's items
 * @return {Array} - a new array of items
 */
Collection.prototype.toArray = function(){
   "use strict";
   var arr = [], o;
   for(o in this.coll){
      arr.push(this.coll[o]);
   }
   return arr;
};

/**
 * Collection.keys() - return an array of item keys from the collection.
 * @return {Array} - an array of key values.
 */
Collection.prototype.keys = function(){
   "use strict";
   var k = [], o;
   for(o in this.coll){
      k.push(o);
   }
   return k;
};
```

Any time you create an object definition, especially one that you might use in a number of different applications, you should write some code to test the object.

```
/**
 * Test suite for this object definition.
 */
var collTest = function(){
   "use strict";

   // Run tests on all methods..
   var c = new Collection();

   console.log("*** add() tests***");
   if(c.add("one", "First item")){
      console.log("Pass: added 'one'");
   } else {
      console.log("Fail: 'one' not added");
   }
   if(c.add("one", "New First item", true)){
      console.log("Pass: updated 'one'");
   } else {
      console.log("Fail: 'one' not updated");
   }
   if(c.add("one", "First item")){
      console.log("Fail: updated 'one' when shouldn't have");
   } else {
      console.log("Pass: correctly didn't update 'one'");
   }
   if(c.add("two", "Second item")){
      console.log("Pass: added 'two'");
   } else {
      console.log("Fail: 'two' not added");
   }
   if(c.add("three", "Third item", true)){
      console.log("Pass: added 'three'");
   } else {
      console.log("Fail: 'three' not added");
   }
   if(c.add("four", "Fourth item", false)){
      console.log("Pass: added 'four'");
   } else {
      console.log("Fail: 'four' not added");
   }

   console.log("***item() tests***");
   var key = "one";
   var item = c.item(key);
   if(item){
      console.log("Pass: retrieved "+key+":"+item);
   } else {
      console.log("Fail: could not retrieve "+key);
   }
   key = "none";
   var item = c.item(key);
   if(item){
      console.log("Fail: wrongly retrieved "+key+":"+item);
   } else {
      console.log("Pass: did not retrieve "+key);
   }
   console.log("***exists() tests***");
   var key = "one";
    if(c.exists(key)){
      console.log("Pass: states " + key + " exists.");
   } else {
      console.log("Fail: states " + key + " does not exist.");
   }
   var key = "none";
   if(c.exists(key)){
      console.log("Fail: states " + key + " exists.");
   } else {
      console.log("Fail: states " + key + " does not exist.");
   }

   console.log("***toArray() tests***");
   var a = c.toArray();
   if(a){
      console.log("Pass: retrieved " + a.join(', '));
   } else {
      console.log("Fail: array not returned");
   }

   console.log("***keys() tests***");
   var k = c.keys();
   if(k){
      console.log("Pass: retrieved " + k.join(', '));
   } else {
      console.log("Fail: keys not returned");
   }

   console.log("***count() tests***");
   var n = c.count();
   if(n){
      console.log("Pass: count is "+n);
   } else {
      console.log("Fail: count not returned");
   }

   console.log("***remove() tests***");
   var n2 = c.remove("two");
   if((n - n2) === 1){
      console.log("Pass: item successfully removed");
   } else {
      console.log("Fail: item not removed");
   }
   console.log("Status – values: " + c.toArray().join(', '));
   console.log("Status – keys: " + c.keys().join(', '));
   console.log("Status – count" + c.count() + " items in collection");

   console.log("***removeAll() tests***");
   c.removeAll();
   if(c.count() == 0){
      console.log("Pass: all items removed");
   } else {
      console.log("Fail: items still in collection");
   }
   console.log("Status - final collection state = [" + c.toArray().join(', ') + "]");
   console.log("Status - final keys state = [" + c.keys().join(', ') + "]");
};

window.onload = collTest; // Run the tests when the page loads.
```

On loading the application and then examining the browser console, we should see:



```
*** add() tests***                                                    collection.js:139
Pass: added 'one'                                                     collection.js:141
Pass: updated 'one'                                                   collection.js:146
Pass: correctly didn't update 'one'                                   collection.js:153
Pass: added 'two'                                                     collection.js:156
Pass: added 'three'                                                   collection.js:161
Pass: added 'four'                                                    collection.js:166
***item() tests***                                                    collection.js:171
Pass: retrieved one:New First item                                    collection.js:175
Pass: did not retrieve none                                           collection.js:184
***exists() tests***                                                  collection.js:187
Pass: states one exists.                                              collection.js:190
Fail: states none does not exist.                                     collection.js:198
***toArray() tests***                                                 collection.js:201
Pass: retrieved New First item, Second item, Third item, Fourth item  collection.js:204
***keys() tests***                                                    collection.js:209
Pass: retrieved one, two, three, four                                 collection.js:212
***count() tests***                                                   collection.js:217
Pass: count is 4                                                      collection.js:220
***remove() tests***                                                  collection.js:225
Pass: item successfully removed                                       collection.js:228
Status - values: New First item, Third item, Fourth item              collection.js:232
Status - keys: one, three, four                                       collection.js:233
Status - count: 3 items in collection                                 collection.js:234
***removeAll() tests***                                               collection.js:236
Pass: all items removed                                               collection.js:239
Status - final collection state = []                                  collection.js:243
Status - final keys state = []                                        collection.js:244
>|
```

Figure 4.5: Test results shown in the Console window.

These results are fairly easy to interpret, although writing the test code was more effort that would ideally be necessary. We'll look at a software test tool that we can use with Javascript code to make testing code that we write easier (and therefore less likely to be omitted!) in a later chapter.

In this chapter we have discussed:

- How Javascript arrays are implemented and operated
- How the Object structure within Javascript uses a mapping structure to provide access to elements
- How to create custom collection classes that add some useful functionality to a simple collection

Web Sources

Advanced Javascript: Objects, Arrays and Array-like Objects - http://nfriedly.com/techblog/2009/06/advanced-javascript-objects-arrays-and-array-like-objects/

W3CSchools: Javascript Array Object - http://www.w3schools.com/jsref/jsref_obj_array.asp

A re-introduction to Javascript - https://developer.mozilla.org/en/A_re-introduction_to_JavaScript

Create your own collection object in Javascript: http://www.techrepublic.com/article/create-your-own-collection-objects-in-javascript/1044659

Exercises

1. Try to think of one good example of where you could use an array in a program (an indexed list of similar objects) and another for using an object mapping (a list of objects indexed by name).
2. Assume you have need for a bookshelf object in a program. It will be used to store a collection of book objects. Think up a list of properties and methods you think a bookshelf should have – for example, the first property I'd think of would be ***count***, to indicate the number of book in the bookshelf.

Try out these exercises in a console window of a browser:

3. Create an array called ***emails*** with zero elements in it.
4. Add three elements – joe@bloggo.com, fred@smiddy.com and your own email address – to the array using the push() method
5. Enter an expression to show the second element in the array
6. Enter an expression to show how many elements are in the array
7. Add a new email (wilma@bedrock.com) to the array *at index location 5*
8. Display the whole array in the console
9. Enter an if() statement followed by an expression to show either a specific element (e.g. emails[3]) or "Empty" if there is no element there. Note the if() and expression can be all on a single line – it will also need an else part (to show "Empty")
10. Sort the array elements into alphabetical order and re-display it
11. Remove the last (empty) element using pop() and re-display the array
12. Write an expression to show the current index of joe@bloggo.com.