

CS 4530: Fundamentals of Software Engineering

Module 2.2: Test-Driven Development

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Learning Goals for this Lesson

- At the end of this lesson, you should be prepared to
 - Explain the basics of Test-Driven Development
 - Explain the connection between conditions of satisfaction and testable behaviors
 - Begin developing simple applications using TypeScript and Vitest

Non-Goals for this Lesson

- This is **not** a tutorial for Typescript or for Vitest
- We will show you simple examples, but you will need to go through the tutorials to learn the details.

Test-Driven Development



PEOPLE



PROCESSES

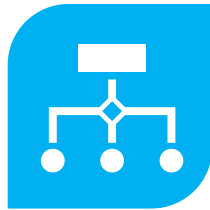


PROGRAMS

PLANNING



ORGANIZING



IMPLEMENTING



Requirements Analysis

User Stories

Testing Conditions of Satisfaction

Review: User Stories

- As a College Administrator, I want to keep track of students, the courses they have taken, and the grades they received in those courses, so that I can advise them on their studies.

*As a <role>
I want <capability>
so that I can <get some benefit>*



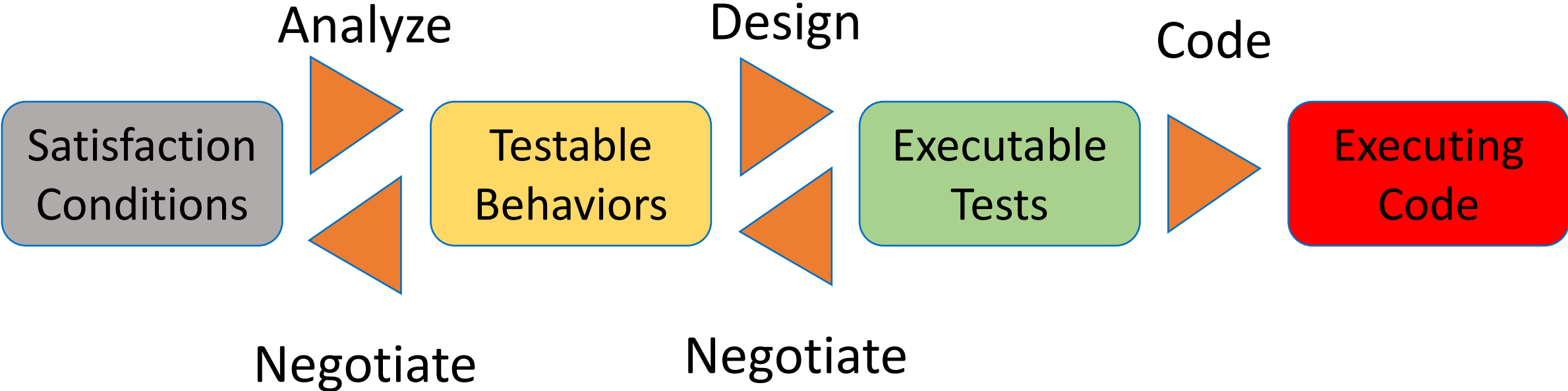
Review: Conditions of Satisfaction

- The college administrator can...
 - Access a persistent database of student records
 - Prevent unauthorized people from accessing or modifying the database
 - Add a new student to the database
 - Add a new student with the same name as an existing student.
 - Retrieve the transcript for a student
 - Delete a student from the database
 - Add a new grade for an existing student
 - Find out the grade that a student got in a course that they took

Test Driven Development (TDD)

- Puts test specification as the critical design activity
 - Understands that deployment comes when the system passes testing
- The act of defining tests requires a deep understanding of the problem
- Clearly defines what success means
 - No more guesswork as to what “complete” means

The TDD Cycle



Analyze and Negotiate

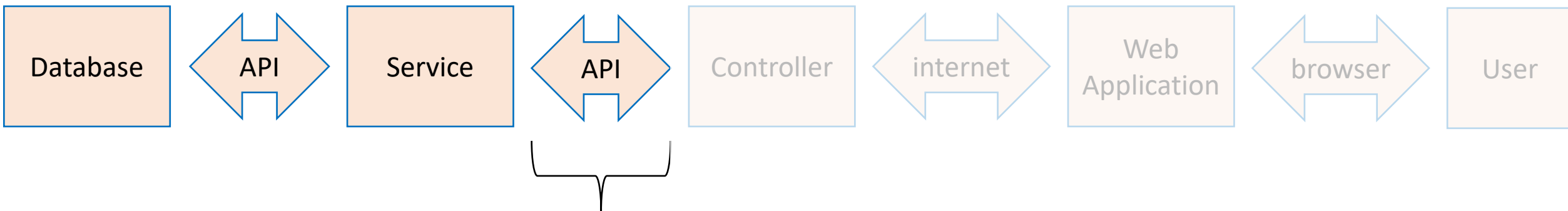
- Analyze:
 - how does the client want the functionality to be delivered?
 - what ambiguities can you find that might make a difference to the client?
- Negotiate
 - discuss these with the client and resolve the differences

Design and Negotiate

- Design the least fragment of the system that could possibly deliver the COS. (YAGNI!)
 - What data would the system need?
 - What operations are needed on the data?
 - Give names to the testable things
- Negotiate
 - Does the data include everything that the client wants?
 - Do the operations include enough to support the COS?
 - Did the client forget something?
 - Are the COS realistic and achievable?

First negotiation: what are we going to test?

A user story is about a person in a specific role, who will need to access a complex application



We test specific parts of the application, still thinking about the user story and conditions of satisfaction

Analyze/Negotiate: what data do we need to worry about?

- We agreed with the client that for each student we will need to save:
 - a student ID
 - the student's name
 - a list of the student's courses and grades
 - for each course the student has taken, the name of the course and the student's grade.
- The client agreed that we don't have to keep track of when the student took the course
 - Keeping it simple for now!!

Now we can design the interface we are going to test.

```
import { StudentID, Student, Course, CourseGrade, Transcript }  
from './types.ts';
```

src/transcript.service.ts

```
export interface TranscriptService {  
  addStudent(studentName: string): StudentID;  
  getTranscript(id: StudentID): Transcript;  
  deleteStudent(id: StudentID): void; // hmm, what to do about errors??  
  addGrade(id: StudentID, course: Course, courseGrade: CourseGrade):  
void;  
  getGrade(id: StudentID, course: Course): CourseGrade;  
  nameToIDs(studentName: string): StudentID[];  
}
```

Analyzing CoS to get testable behaviors

CoS: The college administrator can...

- ...add a new student to the database
- ...add a new student with the same name as an existing student
- ...retrieve the transcript for a student

Testable behaviors:

- addStudent should add a student to the database and return their ID
- addStudent should return an ID distinct from any ID in the database
- addStudent should permit adding a student with the same name as an existing student
- getTranscript, given the ID of a student, should return the student's transcript.
- getTranscript, given an ID that is not the ID of any student, should ...????...

To run the tests, we'll need to design the data in a little more detail

```
// types.ts - types for the transcript service
export type StudentID = number;
export type Student = { studentID: number;
                        studentName: StudentName };
export type Course = string;
export type CourseGrade = { course: Course; grade: number };
export type Transcript = { student: Student; grades: CourseGrade[] };
export type StudentName = string;
```

src/types.ts

The tiniest introduction to Vitest

```
// types.spec.ts
import { describe, expect, it } from 'vitest';
import { type Student } from './types.ts';

const alvin: Student = { studentID: 37, studentName: 'Alvin' };
const bryn: Student = { studentID: 38, studentName: 'Bronwyn' };

describe('the Student type', () => {
  it('should allow extraction of id', () => {
    expect(alvin.studentID).toEqual(37);
    expect(bryn.studentID).toEqual(38);
  });
  it('should allow extraction of name', () => {
    expect(alvin.studentName).toEqual('Alvin');
    expect(bryn.studentName).toEqual('Jazzhands'); // will fail
  });
});
```

You can run tests from the command line

```
% npx vitest --run src/types.spec.ts
```

```
RUN v4.0.16 /Users/rjsimmon/r/transcript-server
```

```
> src/types.spec.ts (2 tests | 1 failed) 4ms  
  > the Student type (2)  
    ✓ should allow extraction of id 1ms  
    × should allow extraction of name 3ms
```

Failed Tests 1

```
FAIL src/types.spec.ts > the Student type > should allow extraction of name  
AssertionError: expected 'Bronwyn' to deeply equal 'Jazzhands'
```

```
Expected: "Jazzhands"  
Received: "Bronwyn"
```

```
> src/types.spec.ts:13:30  
 11|   it('should allow extraction of name', () => {  
 12|     expect(alvin.studentName).toEqual('Alvin');  
 13|     expect(bryn.studentName).toEqual('Jazzhands'); // will fail  
    |                                     ^  
 14|   });  
 15| });
```

or better yet, use an
npm script to automate
this...

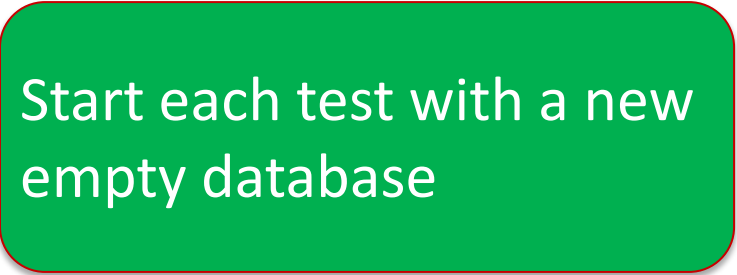
```
Test Files 1 failed (1)  
Tests      1 failed | 1 passed (2)
```

Now we can start writing tests

```
// transcript.service.spec.ts
import { beforeEach, describe, expect, it } from 'vitest';
import { TranscriptDB, type TranscriptService } from './transcript.service.ts';

let db: TranscriptService;
beforeEach(() => {
  db = new TranscriptDB();
});

describe('addStudent', () => {
  it('should add a student to the database and return their id', () => {
    expect(db.nameToIDs('blair')).toStrictEqual([]);
    const id1 = db.addStudent('blair');
    expect(db.nameToIDs('blair')).toStrictEqual([id1]);
  });
});
```



Start each test with a new empty database

Most tests are written in AAA Pattern: Assemble/Act/Assess

```
describe('addStudent', () => {  
  it('should add a student to the database and return their id', () => {  
  
    expect(db.nameToIDs('blair')).toStrictEqual([]);  
  
    const id1 = db.addStudent('blair');  
  
    expect(db.nameToIDs('blair')).toStrictEqual([id1]);  
  
  });  
});
```

← Assemble (and verify)

← Act

← Assess

Turn each testable behavior into one or more tests

```
describe('addStudent', () => {
  it('should return an ID distinct from any ID in the database',
    () => {
      // we'll add 3 students and check to see that their IDs are
      all different.
      const id1 = db.addStudent('blair');
      const id2 = db.addStudent('corey');
      const id3 = db.addStudent('del');
      expect(id1).not.toEqual(id2);
      expect(id1).not.toEqual(id3);
      expect(id2).not.toEqual(id3);
    });
});
```

Tests from Testable Behaviors (2)

```
describe('addStudent', () => {  
  it('should permit adding a student w/ same name as an  
existing student', () => {  
    const id1 = db.addStudent('blair');  
    const id2 = db.addStudent('blair');  
    expect(id1).not.toEqual(id2);  
  });  
});
```

Tests from testable behaviors (4)

```
test('getTranscript should return the right transcript',  
    () => {  
        // add a student, getting an ID  
        // add some grades for that student  
        // retrieve the transcript for that ID  
        // check to see that the retrieved grades are  
        // exactly the ones you added.  
    });
```

Tests from testable behaviors (5)

```
test('getTranscript should throw an error when given a  
bad ID',  
  () => {  
    // in an empty database, all IDs are bad :)  
    // Note: the expression you expect to throw  
    // must be wrapped in a (() => ...)  
    expect(() => db.getTranscript(1)).toThrowError()  
  });
```

Now we can write some code

```
import { type StudentID, type Student, type Course, type CourseGrade,  
        type Transcript } from './types.ts';  
  
export interface TranscriptService { ... }  
  
export class TranscriptDB implements TranscriptService {  
    /** the list of transcripts in the database */  
    private _transcripts: Transcript[] = [];  
  
    /** the last assigned student ID  
     * @note Assumes studentID is Number  
     */  
    private _lastID: number = 0;  
  
    constructor() {}  
  
    // etc
```

Code (2)

```
/** Adds a new student to the database
 * @param {string} newName - the name of the student
 * @returns {StudentID} - the newly-assigned ID for the new student
 */
addStudent(newName: string): StudentID {
  const newID = this._lastID++;
  const newStudent: Student = { studentID: newID,
                                studentName: newName };

  this._transcripts.push({
    student: newStudent, grades: []
  });
  return newID;
}
```

A quick word about cleanup

Start each test with a new empty database

```
let db: TranscriptService;  
beforeEach(() => {  
    db = new TranscriptDB();  
});
```

OR

```
let db: TranscriptService;  
beforeAll(() => {  
    db = new TranscriptDB();  
});
```

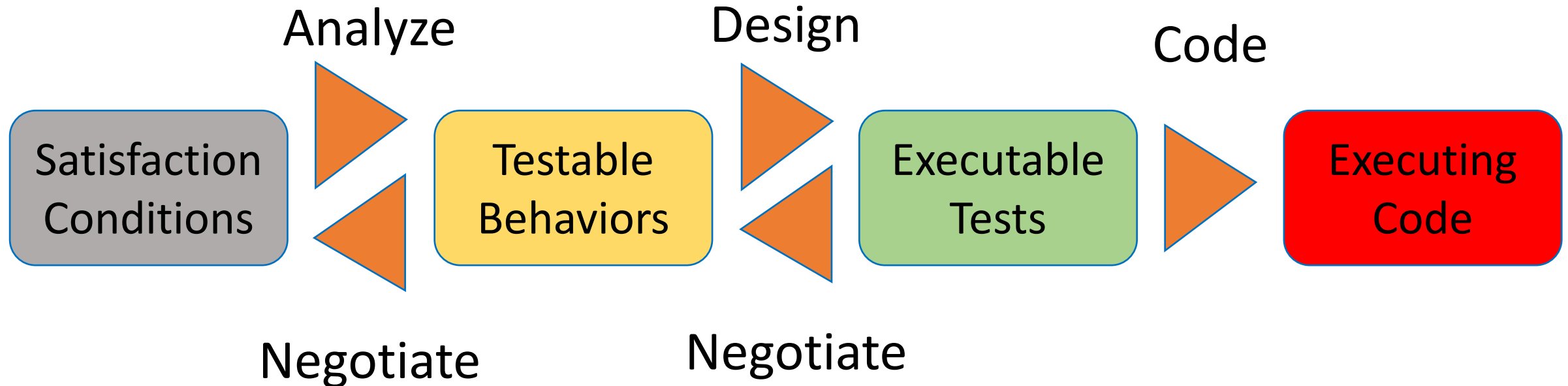
Create one database at the very start

```
beforeEach(() => {  
    db.clear([]);  
});
```

Start every test with the database cleared out

- Use `afterEach()` if needed.

Review: Here is the process we followed



Review: CoS to testable behaviors to TDD

CoS: The college administrator can...

- ...add a new student to the database

Testable behaviors:

- addStudent should add a student to the database and return their ID
- addStudent should return an ID distinct from any ID in the database

It's the end of the lesson, so you should be prepared to:

- Explain the basics of Test-Driven Development
- Explain the connection between conditions of satisfaction and testable behaviors
- Begin developing simple applications using TypeScript and Vitest