Spectrophotometer

Bio Lab Part #2

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Content

Contribution Breakdown

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Team management	25%	25%	25%	25%	100%
Sec 1: Custom Statement of Requirement		100%			100%
Sec 2: System Requirements	70%			30%	100%
Sec 3: Functional Requirements Specification	15%	35%	35%	15%	100%
Sec 4: User Interface Specification			20%	80%	100%
Sec 5: Domain Analysis	30%	10%	30%	30%	100%
Sec 6: Plan of Work		100%			100%

1. Customer Statement of Requirements

With the development of computer technology, many things can be precisely simulated by computer software, which has the advantages, such as simplicity, convenience, inexpensiveness. For instance, experiments in lab, sometimes, can be replaced by computer applications. A virtual machine (VM) is a software implementation of a machine that can realize almost all functions of a physical machine.

1.1 Problems

Biology is a scientific field which is closely related to experiments. However, a traditional biology class in high school or college always faces to the following problems, such as:

1. Experimental devices and resources are always limited. Students, who want to do experiments in Laboratory, may need to make reservations in advance. Therefore, it's not an easy opportunity to do a bio experiment in laboratory.
2. Some bio-processes or bio experiments take relatively long time, and nobody can speed it up in the real world. For instance, some machines, before using them, take an hour to be warmed up, and take another hour to get result. For some simple experiment, it's kind of waste of time. However, without knowing how to operate the machine, students may feel confused.
3. For some experiments, a small mistake may make the whole experiment incorrect. The students cannot fix the mistake even they know they have done something wrong. The only way to get a correct result is to do it again.
4. Sometimes, before doing an experiment, a student needs to prepare for it. For example, he needs to get familiar with how to use the experimental machine. In most cases, however, an instruction book is far away from enough.
5. It is difficult to test the students' experiments skills, because a bio experiment includes many steps. A correct result cannot guarantee all steps are correct. However, it is unrealistic that a teacher examines all steps of each student.
6. Physical machines always require constant maintenance. For some types of machines, their components are not manufactured anymore. In that case, they cannot be used, which is sort of waste of money.
7. For students in developing countries, or in universities that do not have sufficient fund to build labs, they lose the opportunity to do experiments.

If problems mentioned above are solved, students, teachers and educational institutes can get lots of benefits. Since computers are widespread, a computer application that simulates a machine is the simplest and cheapest way.

1.2 A virtual Spectrophotometer

We propose to develop a specific virtual biology machine named spectrophotometer which can be used in biology teaching.

1.2.1 What Is the Spectrophotometer?

The spectrophotometer (Figure 1-1) is an instrument which measures the amount of light of a specific wavelength which passes through a medium. Many substances absorb light and

Figure 1-2 A Spectrophotometer

transmit light of wavelengths within the ultraviolet (200 - 400 nm), visible (400 - 700 nm) and near-infrared (700 - 1000 nm) regions of the electromagnetic spectrum. The extent to which a sample absorbs light depends strongly upon the wavelength of light. The absorbance spectrum(Figure 1-2) shows how the absorbance of light depends upon the wavelength of the light. The spectrum itself is a plot of absorbance vs wavelength and is characterized by the

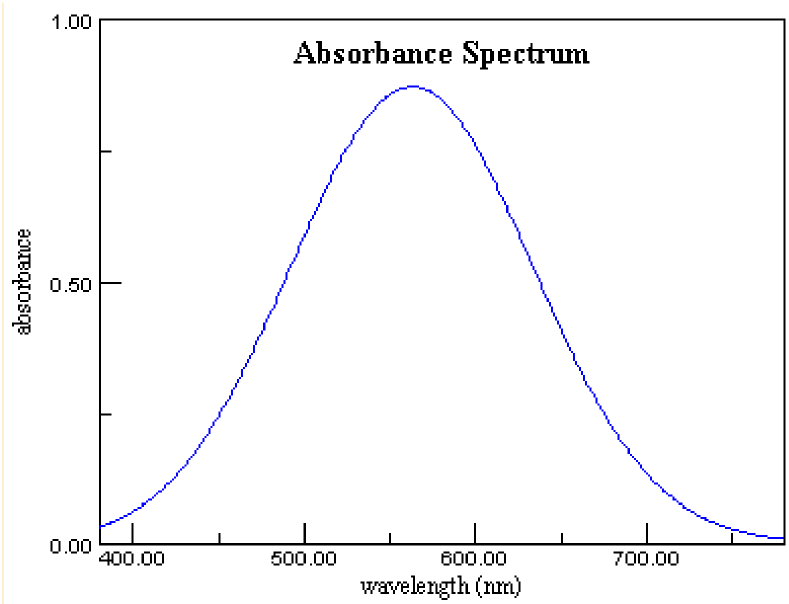

Figure 1-1 Absorbance Spectrum

wavelength (λ_{max}) at which the absorbance is the greatest.

According to Beer's law, the amount of light absorbed by a medium is proportional to the concentration of the absorbing material or solute present. Thus the concentration of a solute in a solution may be determined by measuring the absorbency of light at a given wavelength (λ_{max}). In biology laboratories, for instance, the spectrophotometers are used to measure the concentrations of DNA, RNA or protein samples, λ_{max} of which are already known.

1.2.2 How does A Spectrophotometer work?

A spectrophotometer should include the following components (Figure 1-3):

- A light source
- A focusing device that transmits an intense straight beam of light
- A monochromator to separate the beam of light into its component wavelengths
- A device for selecting the desired wavelength
- A sample holder
- A photoelectric detector
- A meter to display the output of the detector

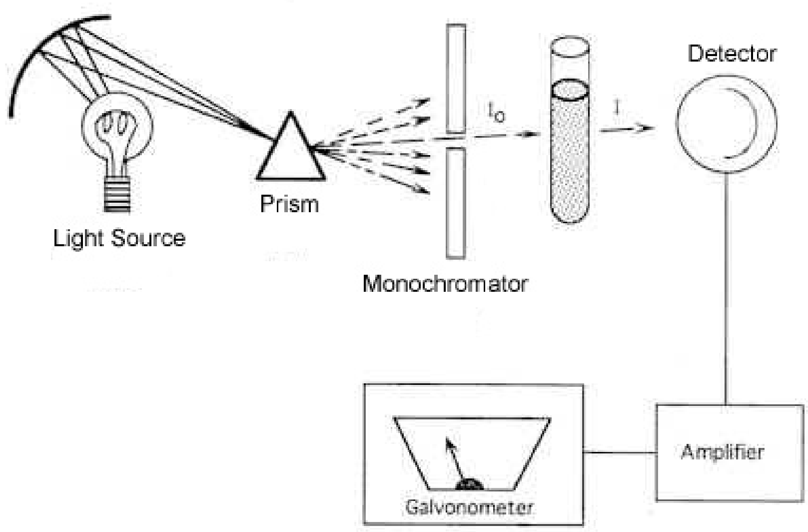

Figure 1-3 Mechanism of the Spectrophotometer

The basic experimental procedure is as following:

- The intensity of light (I_0) passing through a blank is measured. The blank is a solution that is identical to the sample solution except that the blank does not contain the solute that absorbs light.
- The intensity of light (I) passing through the sample solution is measured.
- The experimental data is used to calculate two quantities: the **transmittance** (T) and the **absorbance** (A), as Figure 1-4 shows

$$T = \frac{I}{I_0}$$

$$A = -\log_{10} T$$

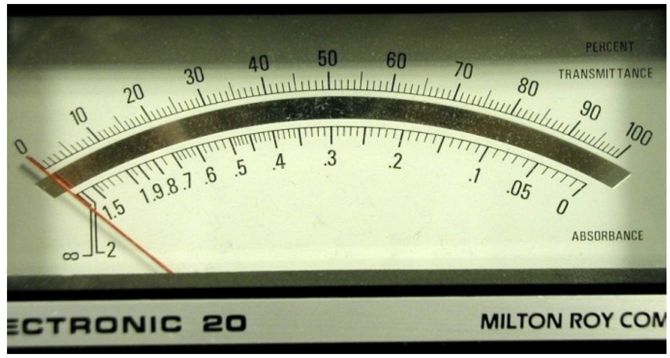

Figure 1-4 meter panel (upper line is Transmittance, bottom line is Absorbance)

- The concentration of an unknown solution can be determined by comparing the absorbance reading of the unknown to the standard curve.

The experimental result may be affected by the following factors:

- The operator doesn't choose the proper wavelength.
- The operator doesn't set a reference solution correctly.
- Unwanted light leaks into the sample.

1.3 Problems Ayalisis

Our design, a virtual lab, can easily solve the problems mentioned in Section 1.1.

From the viewpoint of cost, on the market, a spectrophotometer cost at least $1000, which causes limited laboratorial resources and devices. However, software can run on any computer, which means, taking almost everyone owns a computer, it is almost 0-cost if the software is free. Moreover, it doesn't need maintenance, and it needs fewer teachers in laboratory, which saves maintenance costs and human costs, especially, for institutes that has insufficient fund.

From the students' and teachers' point of view, it can make the experiment easier and save a lot of time. They don't need to go to Laboratory to do bio experiments. Students can preview or review haw to operate the bio machine in term of running the application on their computer. Obviously, it is more convenient. Also, software can implement lots of functions which are impossible in the real world. For example, most applications have functions like "undo" and "redo". And the process that takes one hour in the real world may finish in 1 second in the software.

Of course, there are many free so called virtual bio labs on the internet. However, they all have the several flaws such as lack of accuracy, no animation and only description and so on. Plus, the experiment using spectrophotometer cannot be found on the internet. After our design is accomplished, it will be free because of educational use. Therefore, it can be used widely, and thousands of students, teachers and institute will get benefits.

1.4 Objective of our design

The main purpose of the lab is to familiarize students with the spectrophotometer and its use. Generally speaking, the students first calibrate the instrument using a reference solution of known concentration. The concentration of unknown samples is calculated according to the transmittance value of this solution.

In reflecting on the usefulness of the spectrophotometer simulation, the students enjoyed the individual and repetitive practice they could engage in. They envisioned that this experience would help them with their lab practical exams as well as fine-tune their skills in operating the spectrophotometer in the actual lab. Overall, the students found the virtual labs to be an interface where they could learn and practice in spite of making errors. They also acknowledged that the simulations were realistic and helped in demonstrating certain processes that were not easily represented in the actual lab.

1.5 Glossary of Terms

Table 1-1 shows the terms used in this project.

Term	**Comments**
Absorbance	The intensity of light at a specific wavelength that passes through a sample.
Blank/Transparent	The sample used to calibrate the zero end of the absorbance scale.
Blank Dial	Located on the left front side of the Spectrophotometer, used to set the meter reading to an infinite absorbance on the left side, used for very dark sample where no light passes through.
Concentration	The abundance of a constituent divided by the total volume of a mixture.
Light Production	Light of whichever wavelength that is set shone from the spectrophotometer through the sample.
Sample	The solution that needs to be measured.
Sample Holder	The slot on the top left side of the spectrophotometer that is where you place the test tube with the liquid that you want to find the absorbance of.
Spectrophotometer	A machine used to find the absorbance of a sample by shining a light through it of a specific wavelength.
Test Tube	Glass tube used to contain solution is open at the top and U shaped on the bottom.
Transmittance	The fraction of light in the original beam that passes through the sample and reaches the detector.
Wavelength Dial	The top screen on the Spectrophotometer that indicates at which wavelength, in nanometers, that the light is being shone.
Zero Dial	Located on the right side of the Spectrophotometer, used to set the meter reading to zero absorbance on the right side of the meter, used for when 100% of light is transmitted.

Table 1-1 Terms

2. System Requirements

2.1 Enumerated Functional Requirements

In biology class, a virtual spectrophotometer application not only could help students obtain knowledge, but also activate their learning interests. The application can avoid the situation that several students share one spectrophotometer. With it, it is possible that students do not have to go to laboratory. Also, biology lab could reduce the cost by using this application.

From users' point of view, we list the requirements of a virtual spectrophotometer application (as shown in Table 2-1).

In Table 2-1, each requirement is assigned a unique identifier. The middle column shows the priority weight of each requirement, with a greater number indicating a higher priority.

Identifier	Priority	Requirements
REQ1	4	The system should have a power switch which allows the user to switch on the spectrophotometer, and an indicator lamp to show the power state.
REQ2	5	The system should allow users to select wavelength of the transmit light
REQ3	5	The system should allow the user to adjust the needle to the zero scale in term of rotating the zero dial.
REQ4	5	The system should allow the user to adjust the needle to the infinite scale by rotating the blank dial.
REQ5	5	The system should have a meter that has two scales, transmittance and absorbance. The meter should show the result of operations.
REQ6	4	The system should have a test tube rack where the transparent solution and samples are put.
REQ7	5	The system should have a sample holder with a lid in spectrophotometer.
REQ8	3	The system should allow students to make mistakes during operating.
REQ9	1	The system should provide information board where teacher can post information.
REQ10	2	The system should allow the teacher to change concentration values of the samples by entering different values.

Identifier	Priority	Requirements
REQ11	3	The system should be able to differentiate students and teachers while login.

Table 2-1 System Requirements of the Virtual Spectrophotometer Application

REQ1,REQ2,REQ3,REQ4,REQ5 and REQ7 make the spectrophotometer function like a physical one. REQ6 is make the software look like a workbench. Besides the spectrophotometer, other experimental instruments, such as test tubes, also need to be placed on the table. REQ8 makes the software like a real experiment, for, in real world, students are always making mistakes. REQ9 and REQ10 are requirements raised by teachers. They need to get access to the system to modify some values and post some information, which make software useful for the reason that teachers need to protect the students from memorizing the value of each sample.

2.2 Enumerated Nonfunctional Requirements

The non-function requirements contain the following aspects.

1. Functionality:
   Our system should consider a reasonable and feasible data process method. For example, the experiment result presents over the scale or the result shows a negative data.
2. Usability
   The application should be easy to use and contain instructions that make first user easy to operate.
3. Reliability
   The system should consider the expected incorrect operations and deal with it during programming so that the application is robust for the user.
4. Performance
   The application should possess a fast response to one operation. The computing speed, resource consumption are also the design aspects of programming.

Non-functional requirements are show in Table 2-2.

Identifier	Priority	Requirements
REQ12	2	The system should not allow the result point over the scale. If the result is smaller than the smallest scale or larger than the largest scale, the pointer just points to the smallest or largest scale.
REQ13	3	The system should make sense. For instance, if the lid is close, the user cannot put the test tube in it or remove test tube from it. Likewise, if there already has a test tube in the sample holder, the user cannot put another one into it.

Identifier	Priority	Requirements
REQ14	2	The system should provide tool tips to help the user distinguish the dials and display correct operating process.
REQ15	3	The system should give the scientific result of the experiment.

Table 2-2 Non-functional requirements

REQ14 makes the first-time user easier to get familiar with the spectrophotometer. REQ15 means the system should give a higher or lower value (as a physical one does) according to the incorrect order of operations.

2.3 Acceptance Tests

- Acceptance test case for REQ1:

  Ensure the indicator lamp is on and user can operate when the power switch is on.

  Ensure the indicator lamp is off and operations on the spectrophotometer don't make its needle move.

- Acceptance test case for REQ2:

  Ensure users can select and display wavelength of the transmit light during the experiment process.

- Acceptance test case for REQ3:

  Ensure the user can adjust zero of the needle with zero dial during experiment process.

- Acceptance test case for REQ4:

  Ensure the user can adjust blank with the blank dial during experiment process.

- Acceptance test case for REQ5:

  Ensure the meter could show the result of operations, when operating the spectrophotometer.

- Acceptance test case for REQ6:

  Ensure there are transparent solution and samples on the rack.

- Acceptance test case for REQ7:

  Ensure the system has a sample holder with a lid where the samples or bland should be put in spectrophotometer.

- Acceptance test case for REQ8:

Ensure the system could still operate when user don't follow the right experiment steps during the process.

- Acceptance test case for REQ9:

  Ensure the system provides an information board where display the information that posted by teachers in teachers' system.

- Acceptance test case for REQ10:

  Ensure the user can change the value of each solution in term of entering its value.

- Acceptance test case for REQ11:

  Ensure by entering different username and password, teachers and students can enter teachers' interface and students' interface, respectively.

2.4 On-Screen Appearance Requirements

The spectrophotometer is an instrument which measures the amount of light of a specified wavelength which passes through a medium. Our virtual device should simulate every aspects of the real spectrophotometry in order to hone their skill in the actual lab. The "measuring" behavior performs the calculations based on the density of the solution contained in the test tube and the light wavelength and sends a Transform Command to the instrument (Absorbance Meter) needle to display the wavelength. A dial knob can be rotated to set the desired value. The "turning" behavior causes the "measuring" behavior to redo the measurement when a dial is rotated. Similarly, the lid "opening" behavior causes the "measuring" behavior to redo the measurement when the sample holder's lid is opened or closed. The interface should look like Figure 2-1.

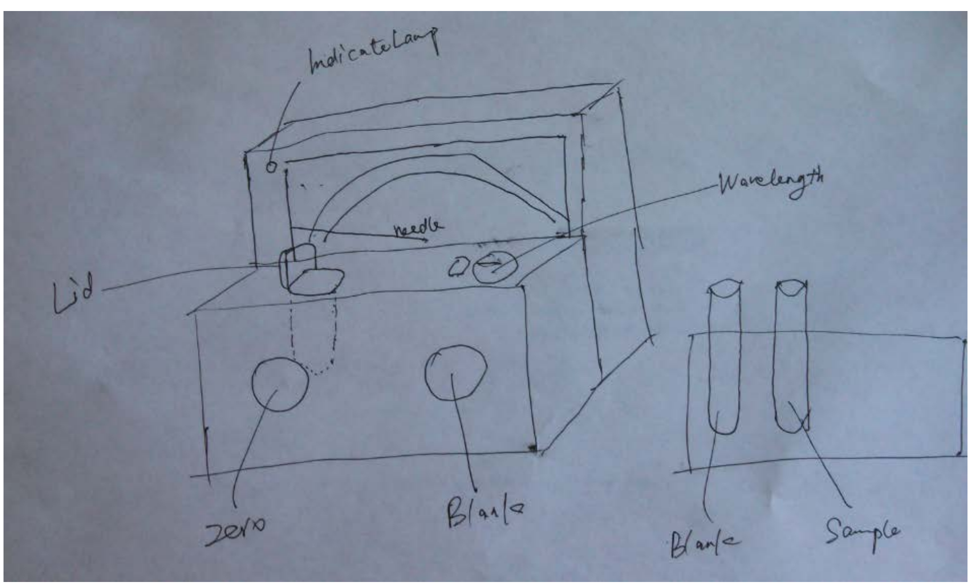

Figure 2-1 Interface Sketch

When students perform these virtual labs, they are likely to make errors that they might notice only in the subsequent steps. Thus, in order to give an opportunity to the user to correct the mistakes, the system should provide him/her with a Back button. As expected, this feature is quite helpful to the student. In cases where the Back button was not implemented, students found that in the event they made an error they were required to start the process all over again, which was frustrating. Also we provide students with next button for students who go to the last step could still back to the previous page.

For teachers who want to send message to students, the information board should be offered on our system interface. Through the login system, teachers can easily enter into the administration interface. We provide teacher an interaction with students through this interface. Teachers can use this system to upload announcements and type in the sample value. Announcements and tips would help them with their lab practical exams as well as fine-tune their skills in operating the spectrophotometer on the information board.

3. Functional Requirements Specification

3.1 Stakeholder

The stakeholders of our system are **Student** and **Teacher**.

3.2 Actors and Goals

Student: to operate the spectrophotometer, to get experimental result and to familiarize with using the machine.

Teacher: to post information and to modify some experimental data.

Meter: to display the result of the experiment.

IndicateLamp: to indicate the power state of the spectrophotometer.

3.3 Casual Description

Table 3-1 shows the casual description of all Use Cases. There are four columns in the following table. The first column is the Use Case Number, and Second and the third column are Name and casual description of each Use Case. The last column is the requirements that each use case covers.

Use Case	Name	Description	Requirements
UC-1	**SwitchOn**	To make the machine start to work	REQ1
UC-2	**AdjustBlank**	To adjust the needle on the meter to the full scale	REQ4, REQ5,REQ8 REQ12,REQ14,REQ15
UC-3	**AdjustZero**	To Adjust the needle on the meter to 0 scale	REQ3, REQ5,REQ8 REQ12,REQ14,REQ15
UC-4	**SelectWaveLength**	To select wave length of the light	REQ2, REQ8,REQ14
UC-5	**UpdateInfoBoard**	To change the content of information board	REQ9
UC-6	**OpenLid**	To open the lid	REQ7,REQ11,REQ14
UC-7	**CloseLid**	To close the lid	REQ7,REQ11,REQ14
UC-8	**SelectTestTube**	To choose one of the test tubes from the rack	REQ6,REQ14
UC-9	**InsertTestTube**	To insert the selected test tube into the chamber	REQ6,REQ7,REQ13
UC-10	**RemoveTestTube**	To remove the test tube in chamber	REQ6,REQ7,REQ13

UC-11	**CheckSampleHolder**	To check sample holder	REQ7
UC-12	**SetSampleValue**	To set the sample value which is to be measured	REQ10
UC-13	**Login**	Allow user to login	REQ11

Table 3-1Use case Casual Description

3.4 Use Case Diagram

Figure 3-1 is the use case diagram of the whole program, which shows the relationship between actors and Use Cases clearly. Use Cases are in the black frame, and outside the frame is actors. We look meter and IndicateLamp as actors because, we believe, first, their roles are more like actors, and, second, it may make the system more clear.

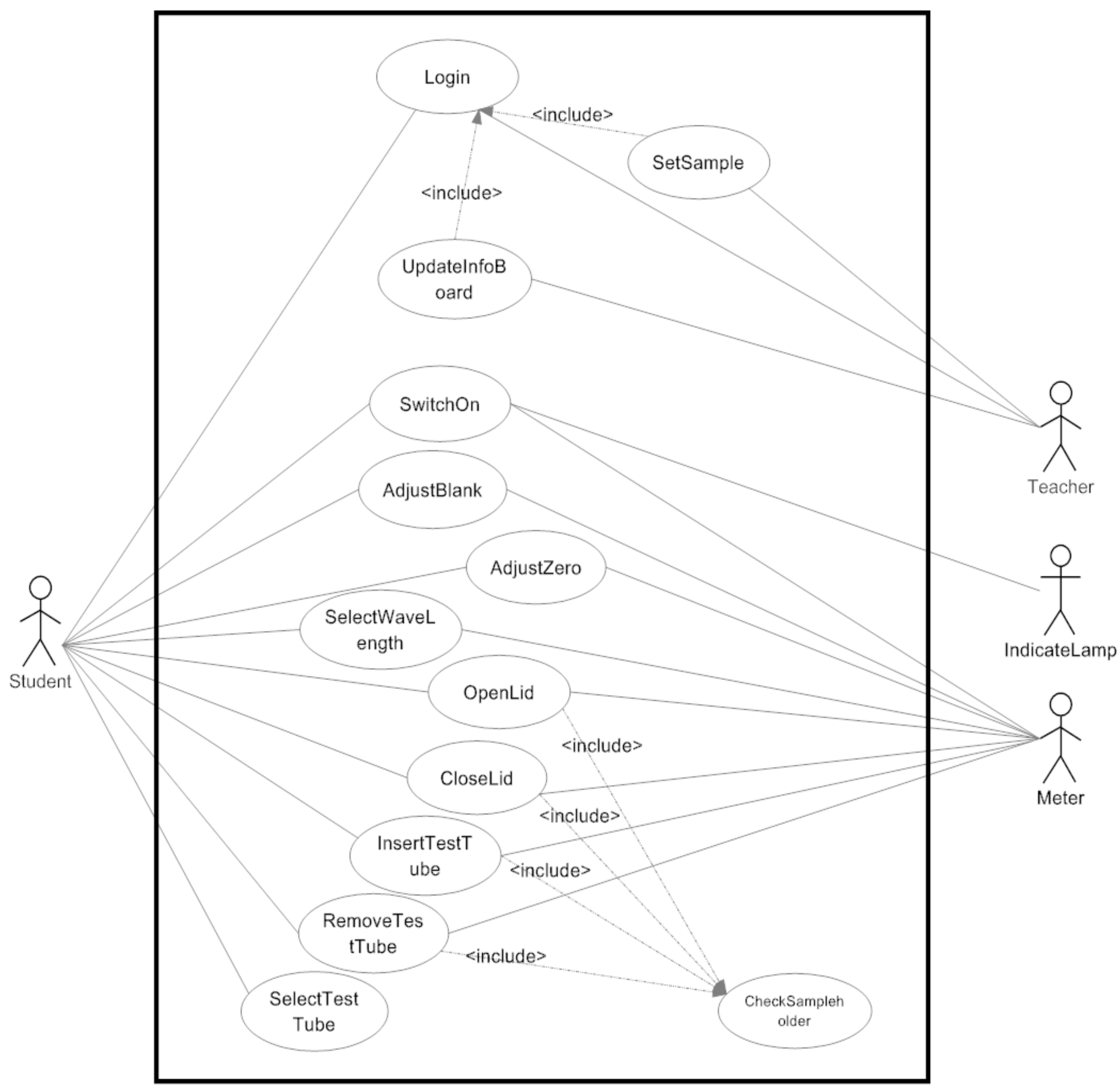

Figure 3-1 Use Case Diagram

3.5 Traceability Matrix

Table 3-2 is the Traceability Matrix Table. PW is short for Priority Weight. Max PW is the highest PW of requirement. The Total PW is the sum of all requirements' PW of each Use Case.

	UC-1	**UC-2**	**UC-3**	**UC-4**	**UC-5**	**UC-6**	**UC-7**	**UC-8**	**UC-9**	**UC-10**	**UC-11**	**UC-12**	**UC-13**
REQ1	X												
REQ2				X									
REQ3			X										
REQ4		X											
REQ5		X	X										
REQ6								X	X	X			
REQ7						X	X		X	X	X		
REQ8		X	X	X									
REQ9					X								
REQ10												X	
REQ11						X	X						X
REQ12		X	X										
REQ13									X	X			
REQ14		X	X	X		X	X	X					
REQ15		X	X										
Max PW	4	5	5	5	1	5	5	4	5	5	5	2	3
Total PW	4	20	20	10	1	10	10	7	12	12	5	2	3

Table 3-2 traceability Matrix

Note that all requirements, functional and non-functional requirement, are included in the Table 3-2, because these non-functional requirements are indispensable for this software. What we can conclude from it is that the first and most important step we need to do is to make the virtual device like a real one. It means that it must look like a real one and users can get result by operating it. Therefore, Use Cases related to teachers are less important than UCs of students.

3.6 Fully-Dressed Description

3.6.1 UC-1 Switch-ON

Use Case UC-1:	SwitchON
Related Requirements:	REQ1
Initiating Actor:	Student

Actor's Goal:	To make the spectrophotometer work, and get the power light on.		
Participating Actors:	PowerSwith, Meter,		
Preconditions:	• The power light is off • The meter cannot move.		
Postconditions:	The power light is on, and the machine starts to work.		
Flow of Events for Main Success Scenario:			
→	1.	**Student** turns the power switch to the State "ON".	
←	2.	**System** (a) signals to the **Student** the machine status, (b) signals to **LightSwitch** to turn the light on.	
←	3.	**System** signals to the signals to **Needle** to be able to move**.**	
→	4.	**Student** starts to operate the spectrophotometer.	

3.6.2 UC-2 AdjustBlank

Use Case UC-2	AdjustBlank	
Related Requirements:	REQ4,REQ5,REQ8,REQ12,REQ14EQ15,REQ15	
Initiating Actor:	Student	
Actor's Goal:	To adjust the pointer to the largest scale	
Participating Actors:	Blank Adjust dial	
Preconditions:	The pointer points to the zero position. The transparent solution is in the cuvette chamber	
Postconditions:	The pointer point to the largest scale position.	
Flow of Events for Main Success Scenario:		
→	1.	**Student** rotates the dial

←	2.	**System** pointer of the scale points to the largest scale position

3.6.3 UC-3 AdjustZero

Use Case UC-3:	AdjustZero
Related Requirements:	REQ3,REQ5,REQ8,REQ12,REQ14,REQ15
Initiating Actor:	Student
Actor's Goal:	To calibrate the pointer position strictly to direct to zero scale
Participating Actors:	Zero Adjust dial
Preconditions:	The pointer doesn't point to zero position.
Postconditions:	The pointer points to zero.
Flow of Events for Main Success Scenario:	
→ 1.	**Student** controls the dial
← 2.	**System** pointer of scale points to the zero position

3.6.4 UC-4 SelectWaveLength

Use Case UC-4:	SelectWaveLength
Related Requirements:	REQ2,REQ8,REQ14
Initiating Actor:	Student
Actor's Goal:	Select the desired wavelength of light.
Participating Actors:	Meter
Preconditions:	Desired wavelength is not selected

Postconditions:	Desired wavelength are selected and displayed in namometer appears in the window.
Flow of Events for Main Success Scenario:	
→ 1.	Rotating the wavelength selection knob
← 2.	The corresponding value of length will display on the namometer
→ 3.	Continuing to rotate the knob until a desired wavelength.
← 4.	The value of desired wavelength will display on the namometer.

3.6.5 UC-5 UpdateInfoBoard

Use Case UC-5:	UpdateInfoBoard
Related Requirements:	REQ9
Initiating Actor:	Teacher
Actor's Goal:	Upload information and display on the virtual devices.
Participating Actors:	N/A
Preconditions:	Default information is displayed on information board Teacher has logged in the system.
Postconditions:	Students can see the information posted by teacher when they log in the system.
Flow of Events for Main Success Scenario:	
→ 1.	**Teacher** enters words in the information board.
← 2.	The information board displays the information.

3.6.6 UC-6 OpenLid

Use Case UC-6:	OpenLid		
Related Requirements:	REQ7,REQ11,REQ14		
Initiating Actor:	Student		
Actor's Goal:	Open the lid in order to make it possible to insert or remove cuvette.		
Participating Actors:	Lid		
Preconditions:	• The lid is closed.		
Postconditions:	•The lid is open.		
Flow of Events for Main Success Scenario:			
→	1.	**Student** does the action of uncovering chamber case.	
	2.	include::*CheckChember*	
←	3.	**System** makes the lid open.	

3.6.7 UC-7 CloseLid

Use Case UC-7:	CloseLid
Related Requirements:	REQ7,REQ11,REQ14
Initiating Actor:	Student
Actor's Goal:	Close lid in order to make it possible to get the correct scale.
Participating Actors:	Lid
Preconditions:	• The chamber case is uncovered the cuvette chamber.
Postconditions:	•The chamber case covers the cuvette chamber.

Flow of Events for Main Success Scenario:		
→	1.	**Student** does the action of close the lid.
	2.	<u>include::*CheckChember*</u>
←	3	**System** covers cuvette chamber.

3.6.8 UC-8 SelectTestTube

Use Case UC-8:	SelectTestTube
Related Requirements:	REQ6, REQ14
Initiating Actor:	Student
Actor's Goal:	Select the test tube, and it can be put in the sample holder or the rack
Participating Actors:	Test tube
Preconditions:	• No cuvettes were selected.
Postconditions:	•One of cuvette is selected.
Flow of Events for Main Success Scenario:	
→ 1.	**Student** does the action of selecting a test tube.
← 2.	One test tube is selected, and it can be move to other places.

3.6.9 UC-9 InsertTestTube

Use Case UC-9:	InsertTestTube
Related Requirements:	REQ6,REQ7,REQ13
Initiating Actor:	Student
Actor's Goal:	Insert the cuvette into chamber

Participating Actors:	Selected test tube, lid		
Preconditions:	• A test tube was selected •There is no test tube in sample holder. •The lid is open		
Postconditions:	•A selected test tube is inserted into the sample holder.		
Flow of Events for Main Success Scenario:			
→	1.	**Student** does the action of inserting test tube.	
	2.	include::*CheckChember*	
←	3.	The selected cuvette is inserted into sample holder.	
Flow of Events for Extensions:			
→	1	**Student** intends to insert the selected test tube while **CheckChember** returns a value that indicates the situation will prohibit the insert.	
←	1.a	The chamber is covered by chamber case. Insert action is forbidden.	
←	1.b	There already has a cuvette in chamber. Insert action is forbidden.	

3.6.10 UC-10 RemoveTestTube

Use Case UC-10:	RemoveTestTube
Related Requirements:	REQ6,REQ7,REQ13
Initiating Actor:	Student
Actor's Goal:	Remove the test tube from the sample holder.
Participating Actors:	Test tube in sample holder, sample holder
Preconditions:	• A test tube was selected in the sample holder. •The lid is open

Postconditions:		•A selected test tube is removed from chamber.
Flow of Events for Main Success Scenario:		
→	1.	**Student** does the action of removing test tube.
	2.	include::*CheckChember*
←	3.	The selected test tube is removed from sample holder.
Flow of Events for Extensions:		
→	1	**Student** intends to take the selected test tube out of the chamber **while CheckChember** returns a value that indicates the situation will prohibit the remove.
←	1.a	The chamber is covered by chamber case. Remove action is forbidden.
←	1.b	There has no cuvette in chamber. Remove action is forbidden.

3.6.11 UC-11 CheckSampleHolder

Use Case UC-11:	CheckSampleHolder
Related Requirements:	REQ7
Initiating Actor:	Student, UC-6,UC7,UC9,UC10
Actor's Goal:	Check the validity of operation
Participating Actors:	Student, ChemberCaseState Diagram and CuvetteState Diagram
Preconditions:	• The Lid is pending to open the sample holder • The Lid is pending to cover the sample holder. • The cuvette is pending to be inserted into sample holder. • The cuvette is pending to be removed from sample holder.
Postconditions:	•The OpenLid is allowed/forbidden.

	•The CloseLid is allowed/forbidden. • The InsertTestTube is allowed/forbidden. • The RemoveTestTube is allowed/forbidden.

Flow of Events for Main Success Scenario:

→ 1. Check ChemberCaseState Diagram

→ 2. Check CuvetteState Diagram

← 3. The OpenLid is allowed/forbidden.

← 4. The CloseLid is allowed/forbidden.

← 5. The InsertTestTube is allowed/forbidden.

← 6. The InsertTestTube is allowed/forbidden.

3.6.12 UC-12 SetSample

Use Case UC-12:	SetSample
Related Requirements:	REQ9
Initiating Actor:	Teacher
Actor's Goal:	Set the sample value which will be measured by students
Participating Actors:	
Preconditions:	• The sample tube has default value.
Postconditions:	• The sample tube get the updated value

Flow of Events for Main Success Scenario:

→ 1. Check ChemberCaseState Diagram

→ 2. Check CuvetteState Diagram

←	3.	The OpenLid is allowed/forbidden.

3.6.13 UC-13 Login

Use Case UC-13:	Login
Related Requirements:	REQ11
Initiating Actor:	Teacher,Student
Actor's Goal:	Access to the system
Participating Actors:	N/A
Preconditions:	• System displays a login screen.
Postconditions:	• Users log in their interfaces respectively.
Flow of Events for Main Success Scenario:	
→ 1.	User enters their username and password.
← 2.	System displays main menu on screen.
Flow of Events for Extensions:	
→ 1.	User enters invalid password or username.
← 2.	Reject user from accessing the system.

3.7 System Sequence Diagrams

This section is System Sequence Diagrams for each Use Case. They show the events that external actors generate, their order, and possible inter-system events.

The system Sequence Diagram of UC-1 is as Figure 3-2

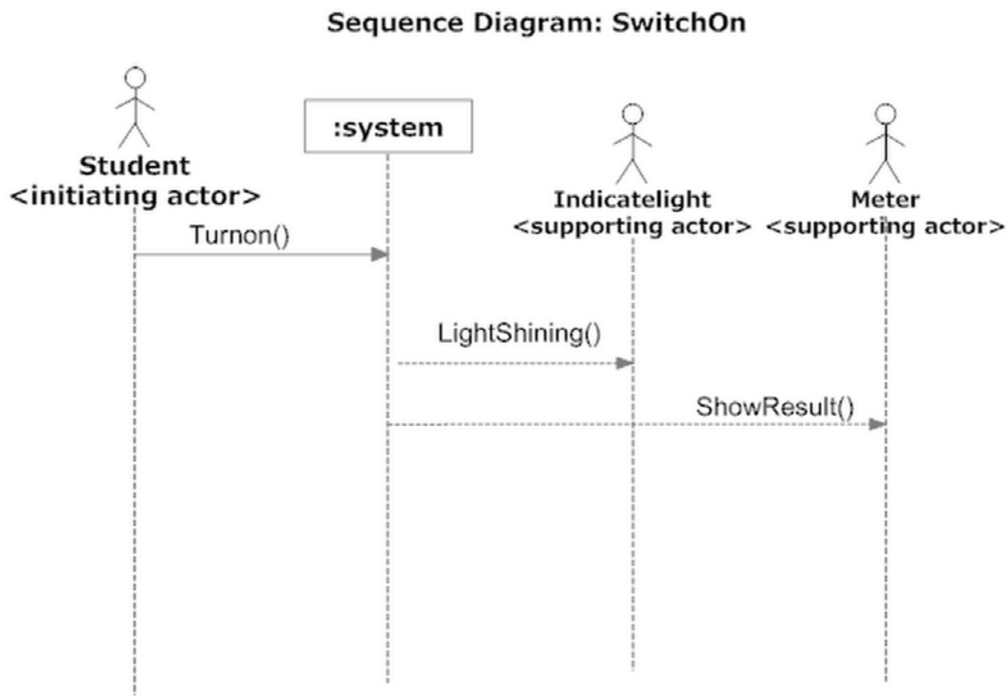

Figure 3-2 Sequence Diagram: UC1-1 SwitchOn

The system Sequence Diagram of UC-2 is as Figure 3-3

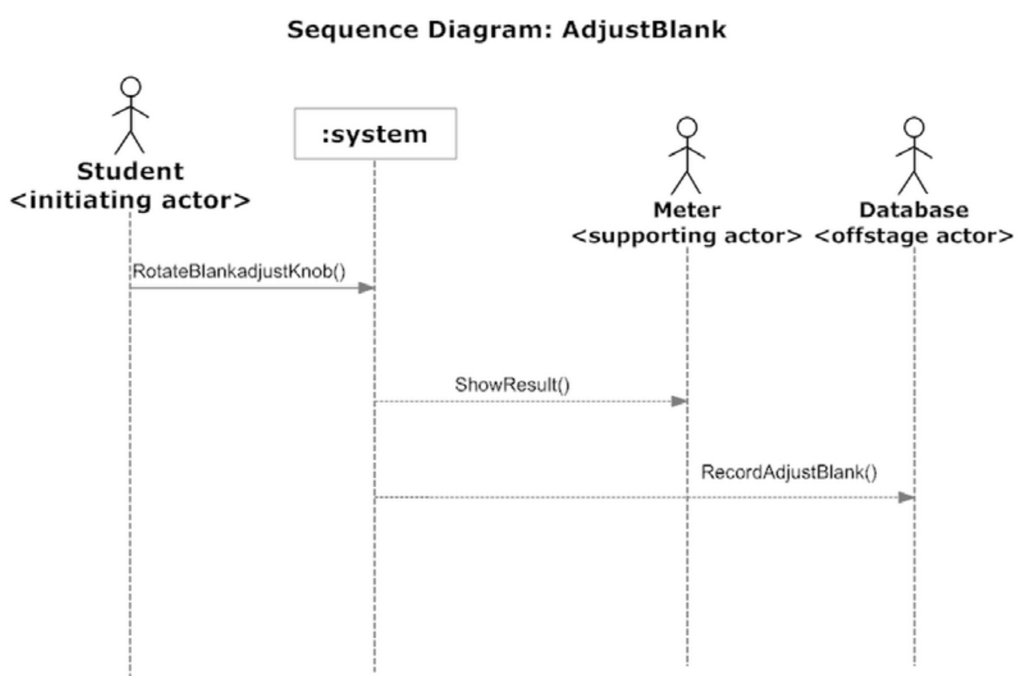

Figure 3-3 Sequence Diagram: AdjustBlank

The system Sequence Diagram of UC-3 is as Figure 3-4

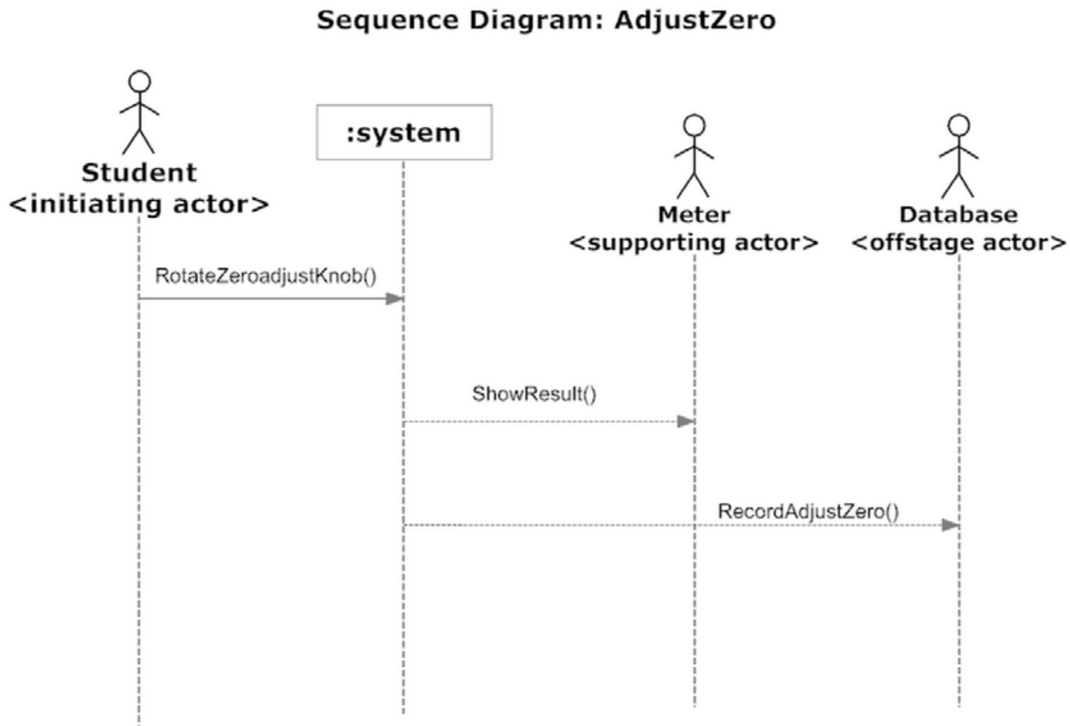

Figure 3-4 Sequence Diagram: AdjustZero

The system Sequence Diagram of UC-4 is as Figure 3-5

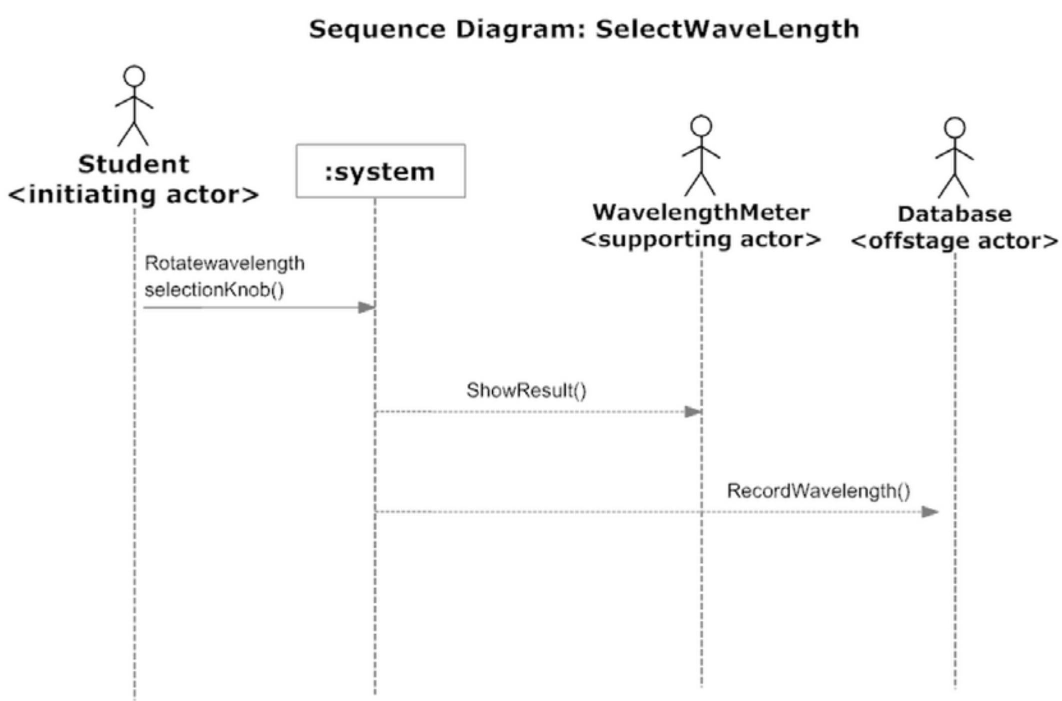

Figure 3-5 Sequence Diagram: SelectWaveLength

The system Sequence Diagram of UC-5 is as Figure 3-6

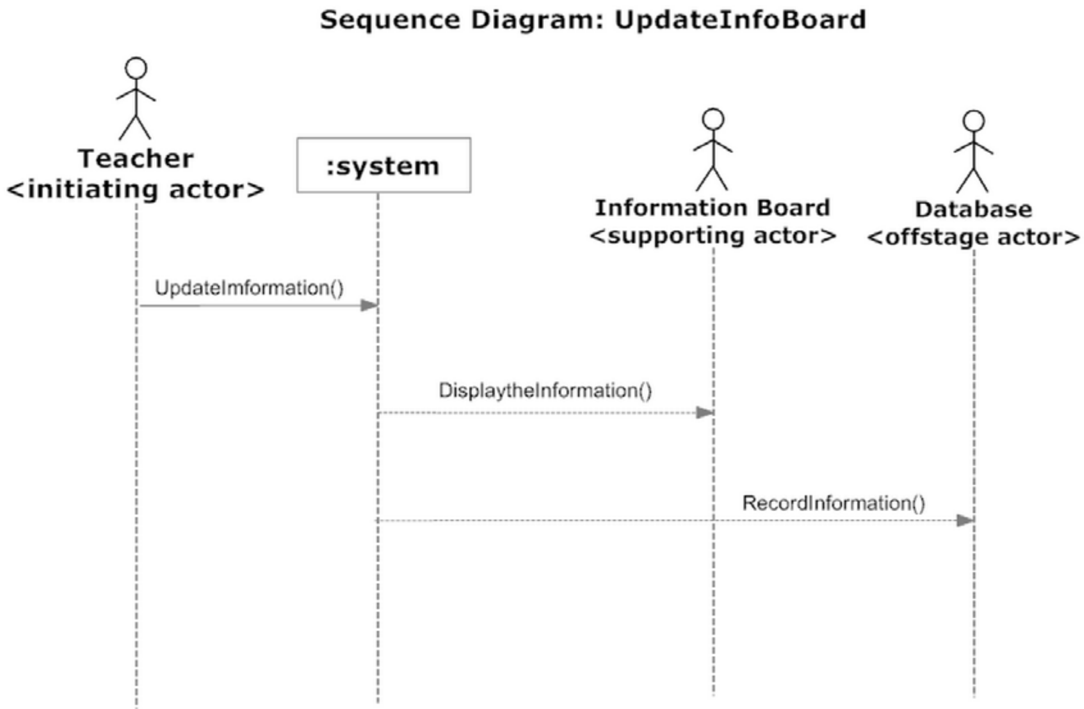

Figure 3-6 Sequence Diagram UpdateInfoBoard

The system Sequence Diagram of UC-6 is as Figure 3-7

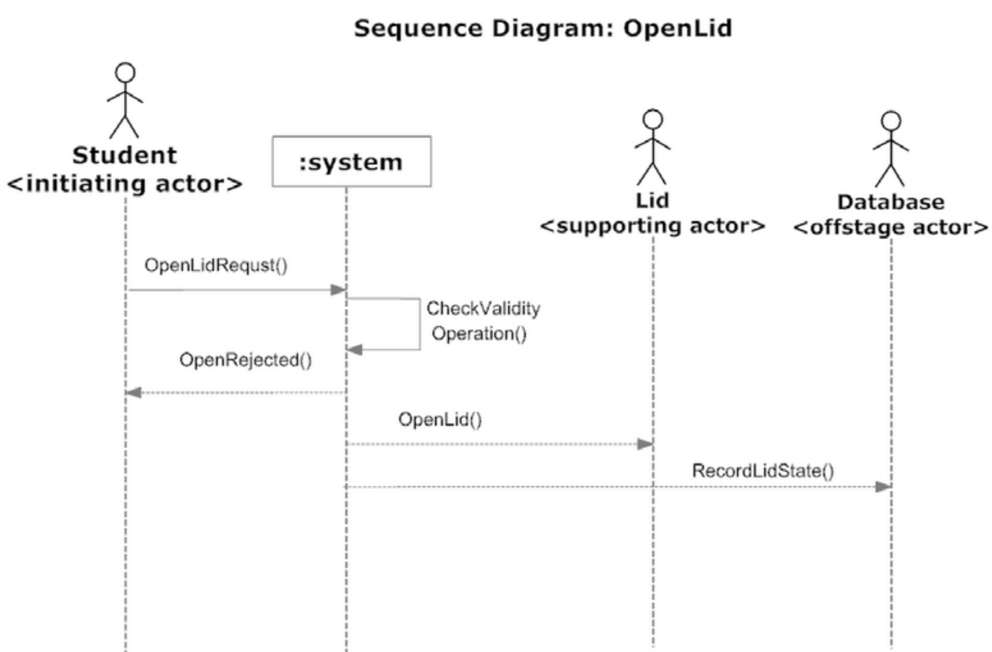

Figure 3-7 Sequence Diagram: OpenLid

The system Sequence Diagram of UC-7 is as Figure 3-8

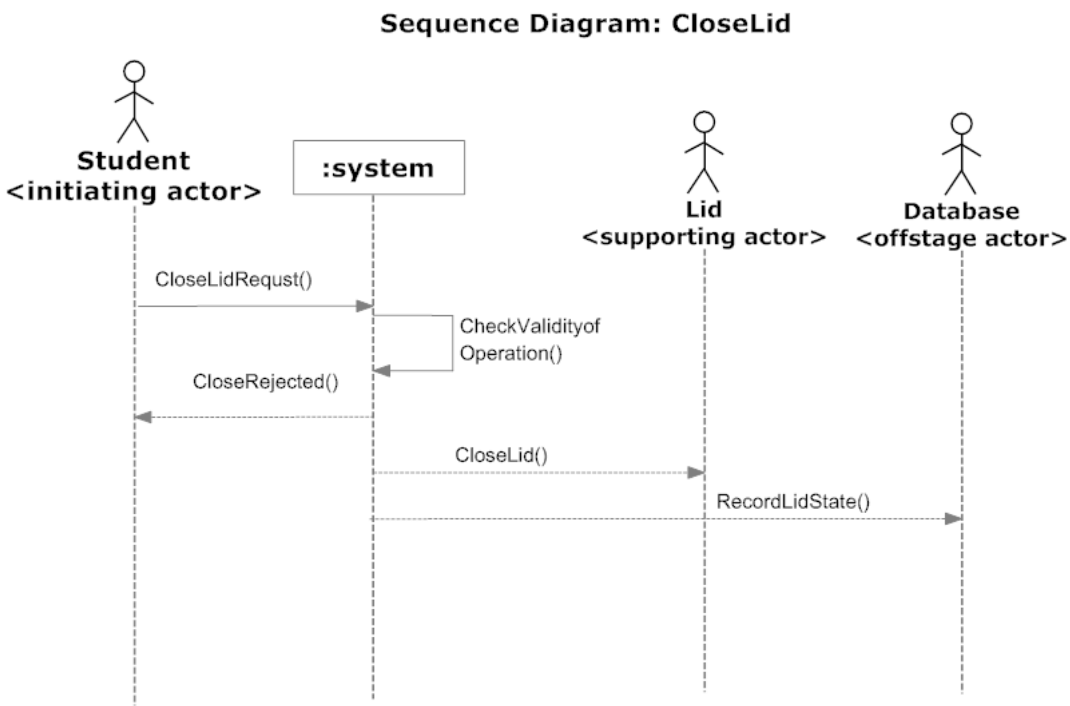

Figure 3-8 Sequence Diagram: CloseLid

The system Sequence Diagram of UC-8 is as Figure 3-9

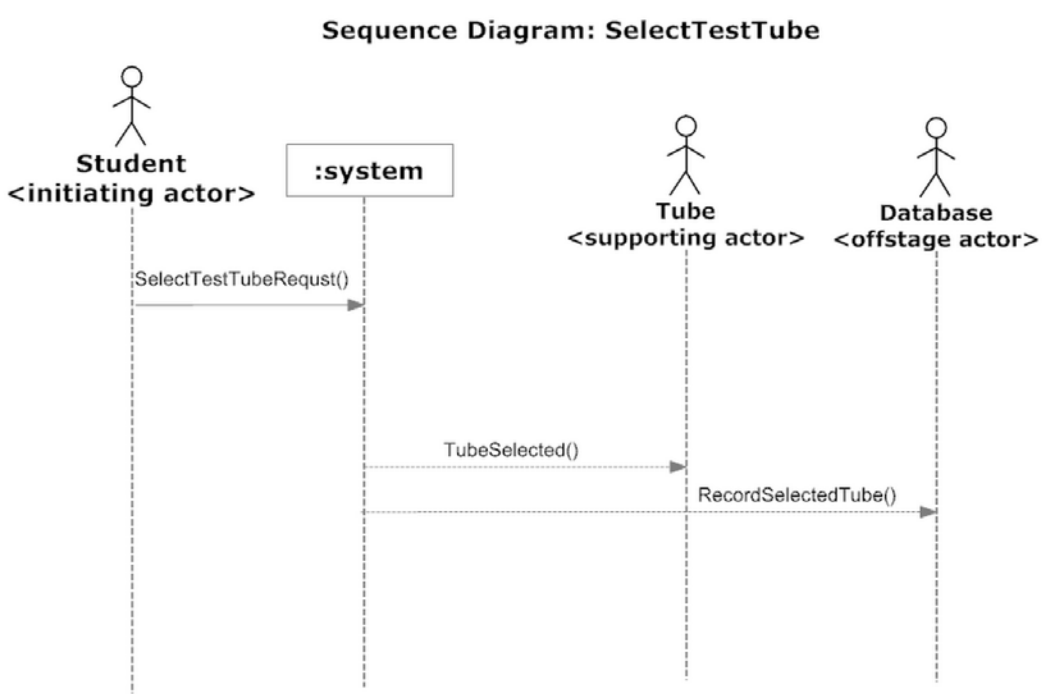

Figure 3-9 Sequence Diagram: SelectTestTube

The system Sequence Diagram of UC-9 is as Figure 3-10

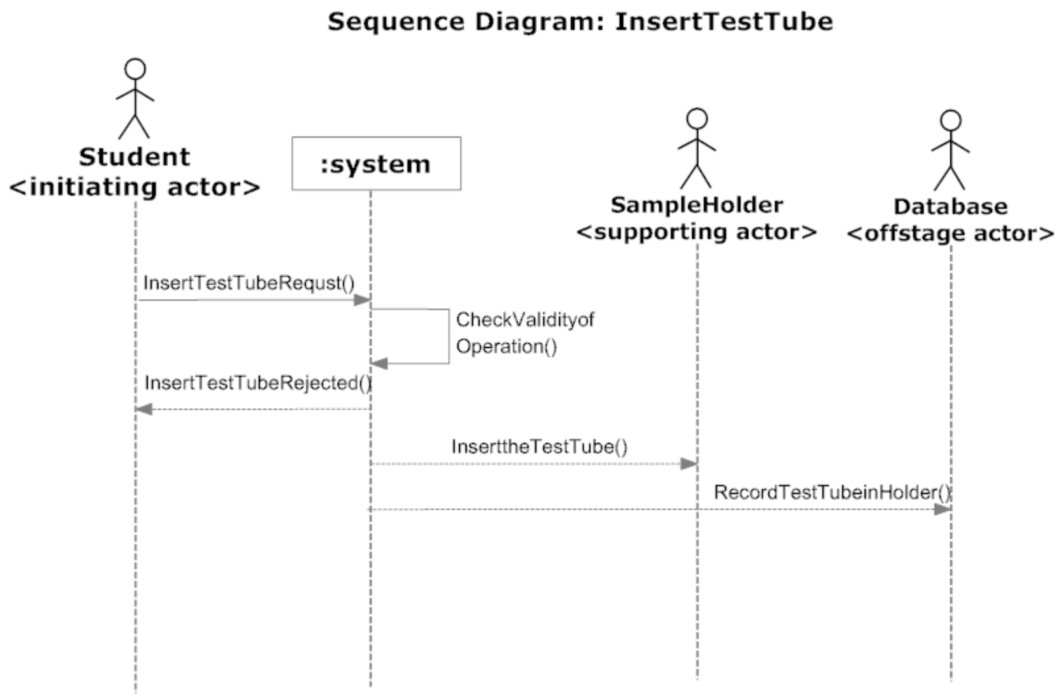

Figure 3-10 Sequence Diagram: InsertTestTube

The system Sequence Diagram of UC-10 is as Figure 3-11

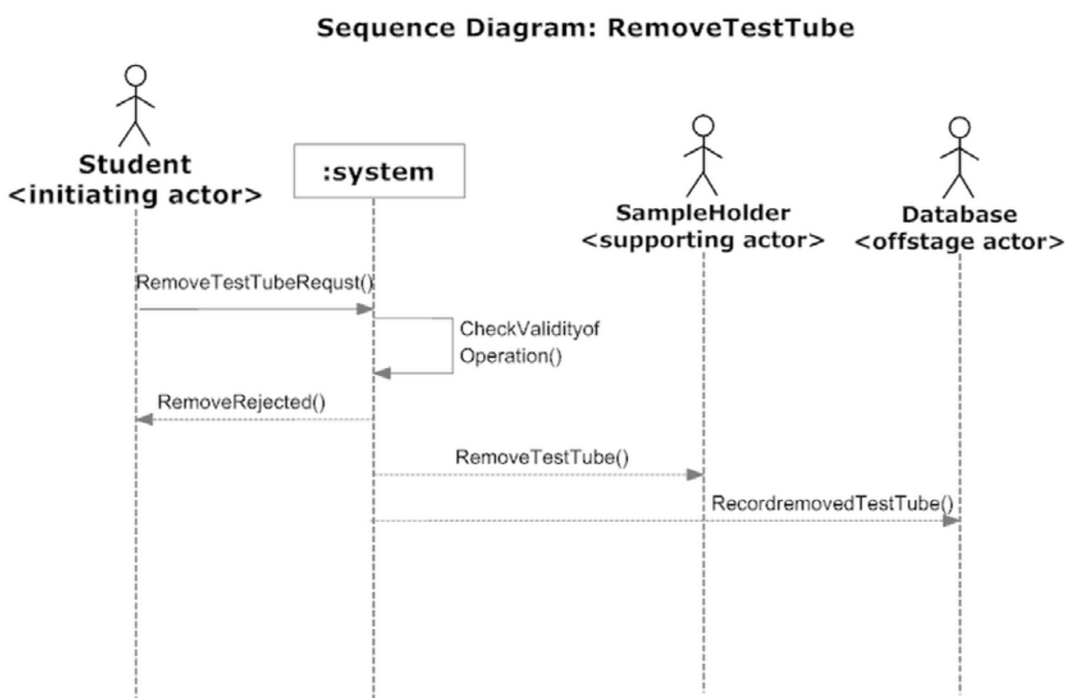

Figure 3-11 Sequence Diagram: RemoveTestTube

The system Sequence Diagram of UC-12 is as Figure 3-12

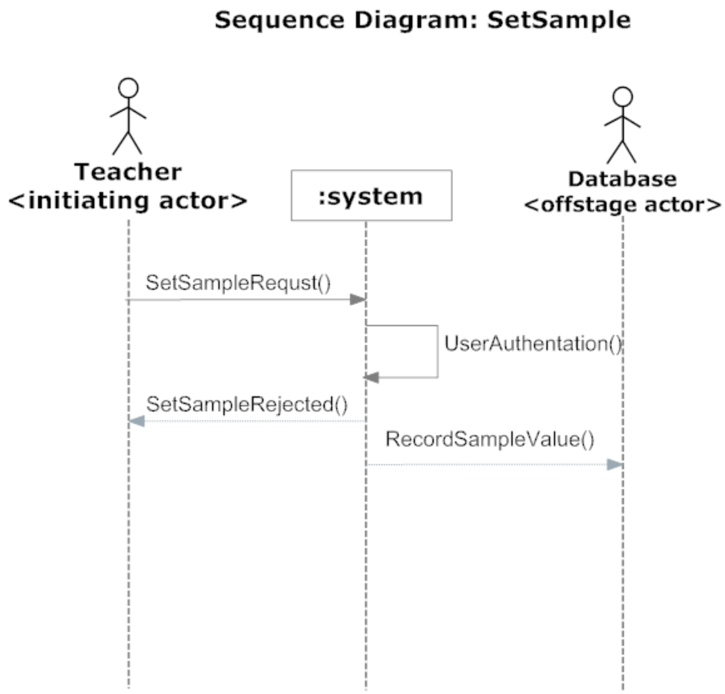

Figure 3-12 Sequence Diagram: SetSample

The system Sequence Diagram of UC-13 is as Figure 3-13

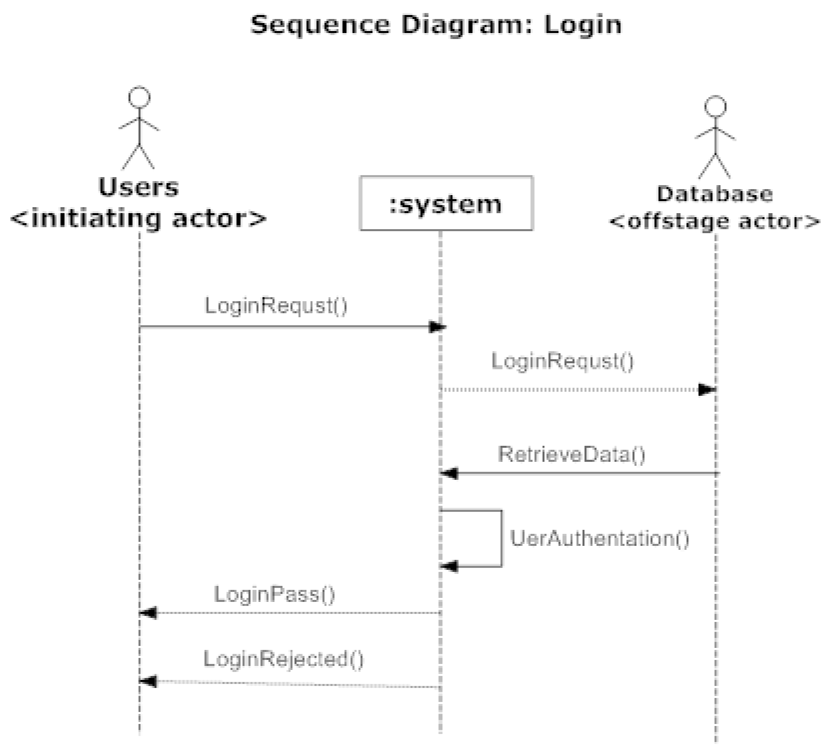

Figure 3-13 Sequence Diagram: Login

4. User Interface Specification

Figure 4-1 shows the specifications of our system user interface. Through our system, students can see the overall system configuration as they see in the real lab.

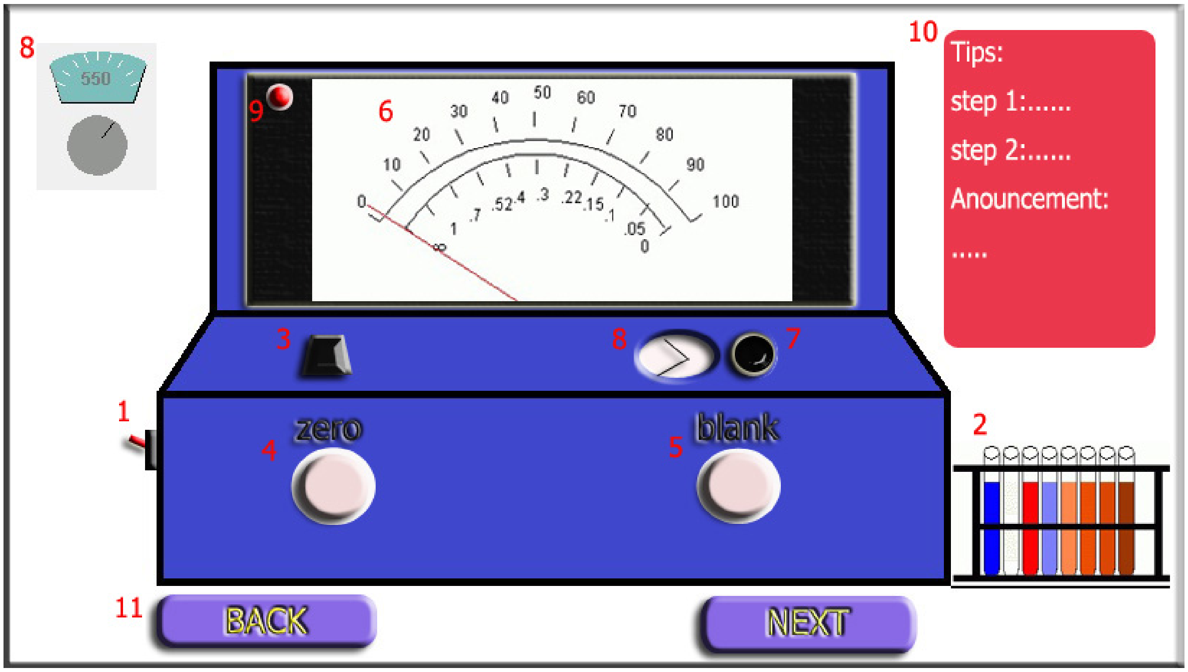

Figure 4-1 Screen snapshot of the spectrophotometry virtual laboratory. 1 on/off switch, 2 rack with test tubes with solutions, 3 sample holder for the test tube, 4 zero control dial, 5 light control dial, 6 meter with needle and pilot light (magnified view shown on top), 7 wavelength control dial for setting the color of the illumination light, 8 magnified view of the wavelength dial, 9indicador lamp,10 information board, 11 back and next button.

4.1 Preliminary Design

In order to get the correct experiment result, students should do experiments step by step via our system:

As you click on the software, you will see our login interface (Figure 4-2) at first glare.

Figure 4-2 Login interface

4.1.1 Teachers' interface

On the above screen, you can choose teachers' account or students' account. Then after valid your username, password and verification code enter a main system interface.

If you are a teacher, you will see the following picture (Figure 4-3)

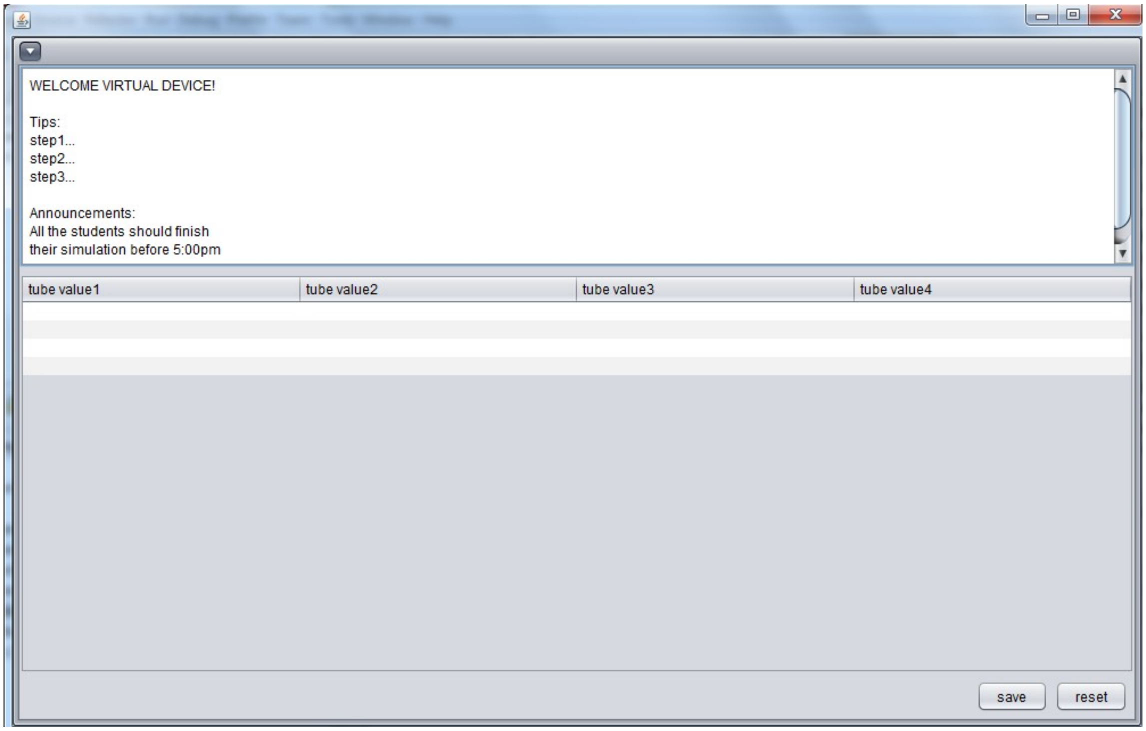

Figure 4-3 Teacher's Interface

1) As a teacher, you can type in the tips and announcement. Students will see these tips and announcements in students interface
2) Also, you can type in the tube value, this value can be used for testing the results.

4.1.2 Students' interface

If you are a student, you will see the figure 4-1

1) Turn on the power switch (labeled as 1 in Figure 4-1). We assumed that the machine has been warmed up.
2) With no cuvette in the chamber, a shutter cuts off all light from passing though the cuvette chamber. Under this condition therefore, the machine may be adjusted to read infinite absorbance (zero% transmittance) by rotating zero adjust knob (labeled as 4 in Figure4-1). *Do not touch this knob again during the rest of the following procedure.*
3) Select the desired wavelength of light at which absorbance will be determined by rotating wavelength selection knob (labeled as 7 in Figure 4-1) until the desired wavelength in nanometers appears in the window. A nanometer, formerly millimicron, equals 10^{-9} meter.

4) Fill the blank (labeled as 2 in Figure 4-1) cuvette with the solvent used to dissolve specimen (often distilled water). Polish to clean, insert into the cuvette chamber (labeled as 3 in Figure 4-1), aligning mark to front. Close chamber cover.
5) Rotate blank adjust knob (labeled as 5 in Figure 4-1) to adjust absorbance to read zero from the meter (labeled as 6 in Figure 4-1).
6) Remove blank cuvette.

4.2 User Effort Estimation

Assume that the virtual device is currently open. Student need know following step to navigate the interface:

i. Choosing student or teacher account and entering the username, password and verification number then click login.
ii. If you are a teacher you can click the text part to upload information or click to enter the test value, while if you are a student, you will see following steps.
iii. Click on the power switch to turn ON or OFF(labeled 1 in Figure 4-1)
Event: “SwitchOn”
iv. Click on the Flip the lid of the cuvette chamber COVERED or UNCOVERED(labeled 3 in Figure 4-1).
Event: “CloseLid”
v. Rotate the Adjust_to_zero_knob(labeled 4 in Figure 4-1)
Event “Adjust_to_zero”
vi. otate the Adjust_to_blank_knob (labeled 5 in Figure 4-1)
Event “Adjust_to_blank”
vii. Drug the test tube to INSERT or REMOVE the test tube to/from the sample holder(labeled 2 in Figure 4-1)
Events: “setTestTube” and “removeTestTube”

5. Domain Analysis

5.1 Domain Model

Domain Model is as Figure 5-1 shows

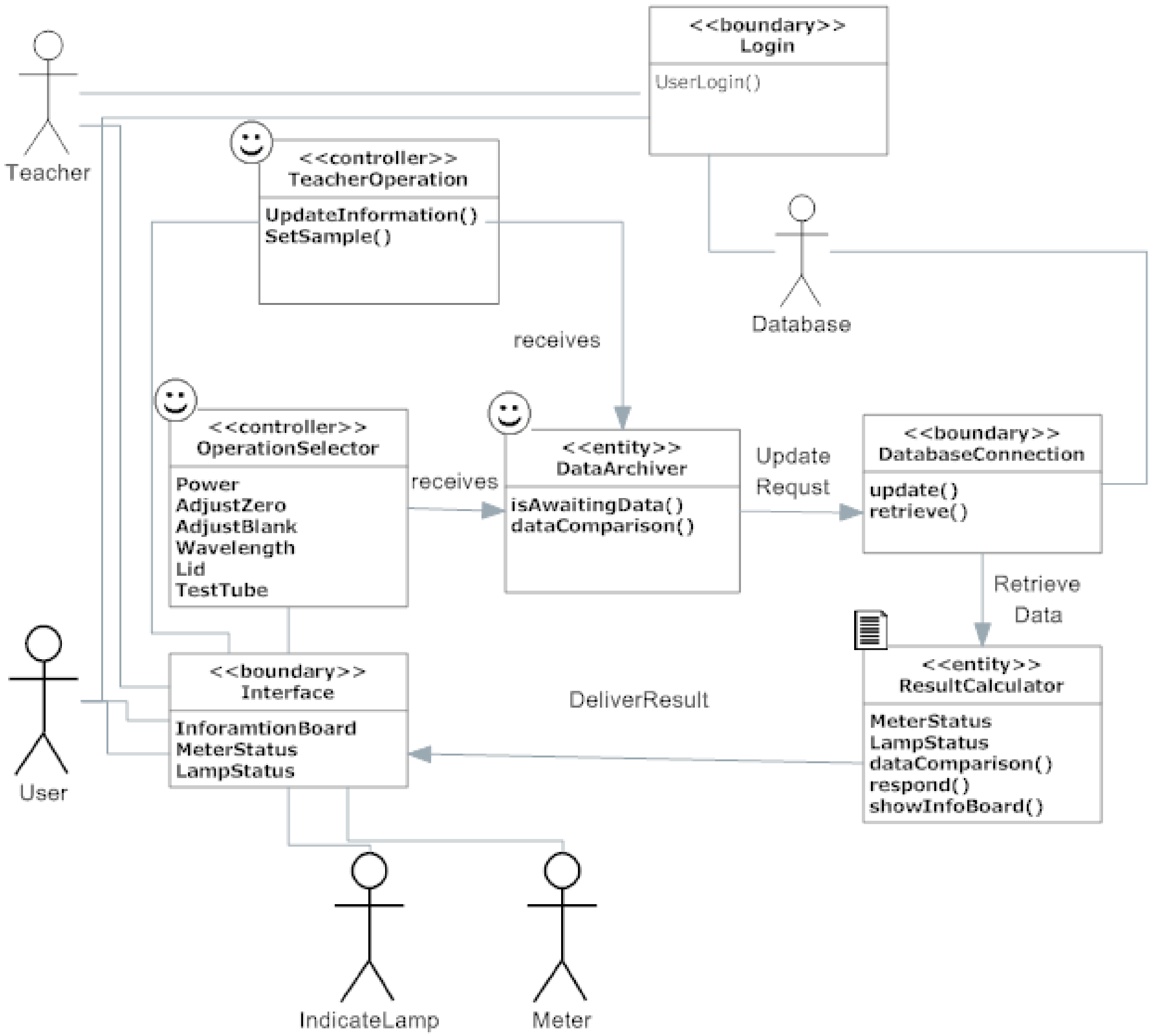

Figure 5-1 Domain Model

5.1.1 Concept definitions

Table 5-1 lists the responsibilities and the worker titles (concept names) to whom the responsibilities are assigned. And each responsibility of a concept has a type “D” or “K” denotes doing vs. knowing, respectively.

Responsibility Description	Type	Concept Name
Provide the user a virtual spectrophotometer as a real spectrophotometer and respond the reasonable results to users with indicate lamp and meter.	K	Interface
Verify the command entered by users is valid or not, and decide which operation should be responded.	D	OperationSelector
Collect and Arrange the data in a right order which can show the real sequence of different operations	D	DataArchiver
Ensure the dataflow between data controller, actor database and Data calculator	D	DatabaseConnection
Compare the data with the reference data, and give a corresponding reaction	D	DataCalculator
Allow teacher to login the administration interface then upload the information and test value of the tube.	D	TeacherOperation

Table 5-1 Responsibility description for the Virtual Spectrophotometer

Users can see our virtual Spectrophotometer from our interface. It is the only way for users to interact with our system. It will display all the reasonable respond to the user's action.

OperationSelector can detect users' command and then figure out the operation of the device. And send corresponding data to DataArchiver.

DataArchiver will receive and collect the data sent by the operation selector. These data can be regarded as the status of different knobs. As we mentioned above, our system will allow students to make mistakes, so they can do any step whenever they want. Considering these aspects, we will give a reasonable respond on our system when students make mistake. However, in the real world, operation sequence and different combination of knobs status will have an influence on the final results. So the Data controller will arrange the data in a right order which can show the real sequence of different operations. Then the data can be sent to database connection.

Database connection can connect the data controller with actor database and Data Calculator. In this concept, data can be updated when receiving the data from data controller. And put these data forward to the actor database and data calculator.

When collecting the data from database connection, the data calculator will compared the data with the reference data. Reference data stand for the all the combinations of operation sequences and knob status. Through this comparison, the system could exactly know the operation sequence and different knob status. Then the system will give a corresponding reaction to the actor meter and actor indicator lamp.

5.1.2 Association Definitions

Association Definitions is as Table 5-2 shows

Concept pair	Association description	Association name
User →OperationSelector	User behaves an operation (turn on device, adjust zero/ blank, select/insert/remove test tube, open/close lid)	OperationRequest
OperationSelector →DataArchiver	Record the user operation, and send it to DataArchiver	OperationDataDeliver
DataArchiver →DatabaseConnection	Generate the update request to DatabaseConnection	DataUpdateRequest
DatabaseConnection ←→Database	Update and Retrieve data from Database	DateTransaction
DatabaseConnection →ResultCalculator	Send the retrieved information to ResultCalculator	DataRetrieve
ResultCalculator →Interface	Deliver the result to Interface	DeliverResult
Interface→User	Show the result to user	DisplayResult
Interface →IndicateLamp	Show the IndicateLamp result(shining or blank)	ShowIndicateLampResult
Interface→Meter	Show the Meter result(the angle needle spins)	ShowMeterResult
TeacherOperation→ DataArchiver	Send updated information and sample value	TeacherOperationRequst

Table 5-2 Association Definitions

5.1.3 Attribute definitions

Attribution Definitions is as Table 5-3 shows

Concept	Attributes	Attribute Description
Interface	user input	Accept user's input and provide the data to the related block
	display results	Display the Absorbance/Transmittance of the test tube
OperationSelector	Power	Identify if the device has been on
	AdjustZero	Identify if the device has been zero setting
	AdjustBlank	Identify if the device has been full-scale setting

Concept	Attributes	Attribute Description
	choose wavelength	Indicate the light wavelength
	lidControl	Indicate the chamber lid status
	tubeSelection	Identify the testing tube
DataArchiver	isAwaitingData	Indicate if the data has been completely collected
	dataComparison	Identify the meaning of the data
Database Connection	update	Send data to next step
Data Calculator	isAwaitingData	Indicate if the data has been completely received
	dataComparison	Identify the meaning of the data
	respond	Give a reasonable reaction to actors
TeacherOperation	UpdateInfo	Enter information that shows to students.
	SetSample	Enter the value of each sample.

Table 5-3 Attribution Definitions

5.1.4 Traceability Matrix

Traceability Matrix is as Table 5-4 shows

Use Case	PW	Interface	OperationSelector	DataArchiver	Database Connection	DataCalculator	TeacherOperation
UC-1	4	X	X				
UC-2	20	X	X	X	X	X	
UC-3	20	X	X	X	X	X	
UC-4	10	X	X	X	X	X	
UC-5	1	X					X
UC-6	10	X	X				

UC-7	10	X	X				
UC-8	7	X	X				
UC-9	12	X	X				
UC-10	12	X	X				
UC-11	5			X	X	X	
UC-12	2						X
UC-13	3						X

Table 5-4 Traceability Matrix

5.2 System Operation Contracts

Operation SwitchOn is the first step. Table 5-5 shows the system operation contracts for SwitchOn.

Operation	SwitchOn
Preconditions	• IndicatorLampStatus= false (off) • VirtualMachineStatus=false(off) • The meter keep stable in initial position
Postconditions	• IndicatorLampStatus=true(on) • VirtualMachineStatus=true(on) • NeedleStatus ≠ Null

Table 5-5 System Operation Contract for SwithOn

After switching on the machine, users start to do the simulation step by step. We design our system according to what happens in the real world. In other words, our system makes students feel that they are in a real lab. They can do everything they can do in the real lab by using our software. For example, they don't have to following the correct scenario of the experiment, even though what they do will result in an incorrect value. Table 5-6, Table 5-7 and Table 5-8 show the system operation contracts for different knobs. These contracts are in a correct order of using spectrophotometer.

Operation	AdjustBlank
Preconditions	• NeedleStatus=0 • IsSampleHolder= 0 (transparent solution)
Postconditions	• NeedleStatus=Full scale

Table 5-6 System Operation Contracts for AdjustBlank

Operation	AdjustZero
Preconditions	• NeedleStatus ≠ Null
Postconditions	• NeedleStatus=0

Table 5-7 System Operation Contracts for AdjustZero

Operation	SelectWavelength
Preconditions	• Rotating the wavelength selection knob.
Postconditions	• Corresponding wavelength is selected.

Table 5-8 System Operation Contracts for SelectWaveLength

Teachers can upload information and set concentration for all samples. The following Tables, Table 5-9 and Table 5-10 are system operation contracts for these two UCs.

Operation	UpdateInfoboard
Preconditions	• Teachers login the system successfully LoginTeacherSystem=1
Postconditions	• Information board display on the screen.

Table 5-9 System Operation Contracts for UpdateInfoboard

Operation	SetSample
Preconditions	• Teachers login the system successfully LoginTeacherSystem=1
Postconditions	• Information board display on the screen.

Table 5-10 System Operation Contracts for SetSample

Following contracts(as shown in Table 5-11, Table 5-12, Table 5-13, Table 5-14 and Table 5-15) are all related to the test tube. We put them in the following order for the reason that they meet the experiment scenario.

Operation	OpenLid
Preconditions	• LidStatus=0(closed)
Postconditions	• LidStatus=1(open)

Table 5-11 System Operation Contracts for OpenLid

Operation	SelectTestTube
Preconditions	• IsTubeSelected=No
Postconditions	• IsTubeSelected=Yes

Table 5-12 System Operation Contracts for SelectTestTube

Operation	InsertTestTube
Preconditions	• There is no tube in the sample holder. SampleHolderStatus=0 • LidStatus=1(open)
Postconditions	• There is a tube in the sample hold. SampleHolderStatus=1

Table 5-13 System Operation Contracts for InsertTestTube

Operation	CloseLid
Preconditions	• LidStatus=1(open)
Postconditions	• LidStatus=0(closed)

Table 5-14 System Operation Contracts for CloseLid

Operation	RemoveTestTube
Preconditions	• There is a tube in the sample holder. SampleHolderStatus=1

	• The lid is open LidStatus=1(open)
Postconditions	• The selected tube is removed from sample holder. SampleHolderStatus=0

Table 5-15 System Operation Contracts RemoveTestTube

Our system should be in accordance with common sense. For example, the lid status decides whether you can insert or remove the test tube. System operation contracts for CheckSampleHolder are shown in Table 5-16.

Operation	CheckSampleHolder
Preconditions	• LidStatus=1/LidStatus=0
Postconditions	• The InsertTestTube/ RemoveTestTube is allowed/The InsertTestTube/ RemoveTestTube is forbidden

Table 5-16 System Operation Contracts for CheckSampleholder

6. Plan of Work

This project is a sub-project of Virtual Biology Lab, and it is not in our original plan. So we started this project a little later. It may be overdue when we finish and submit the report #1, but we will try our best to catch up all following deadlines.

This part is the schedule of our future work (Table 6-1). We are dedicated to finishing this work step by step. Therefore, our plan can be separate into 5 parts.

1. Preparation Oct.15 –Oct.18
   In this part, we will do the following work:
   i. Revising our Report #1
   ii. Studying previous work
      Because our project is based on a previous "just-started" work, so we need to check what they have done. We can utilize some their work or improve their design.
   iii. Scientific Research
      This virtual machine is designed to be used in education. Therefore, the final result must be in accordance with the truth. That means the result of this virtual machine must be as same as the result that students get on a physical machine even operated incorrectly.
   iv. Learning Java
      We need to keep learning and discuss problems during learning process.
2. Interface Implement Oct. 19-Oct. 26(First Demo)
   At the end of this part, we need to show our first demo of our program and finish part1 of Report #2. Therefore we need the following work:
   i. Drawing picture
      We will use PS to draw every component of the spectrophotometer.
   ii. Interface Design
      We will design where every component is located on the screen. Dials can be rotated by user and needle can move.
   iii. Finishing part1 of Report #2
3. Database Design Oct. 27- Nov. 6 (report #2)
   We will finish Report #2 during this period, and design the structure of database.
4. Full-Feature Completion & Debugging Nov. 7- Dec. 7 (second Demo)
   We will finish all features showed above. For instance, showing scientific result and making operations more reasonable.
5. Finishing project Dec. 8- Dec. 12(final report)
   We will collect all documents and submit final report.

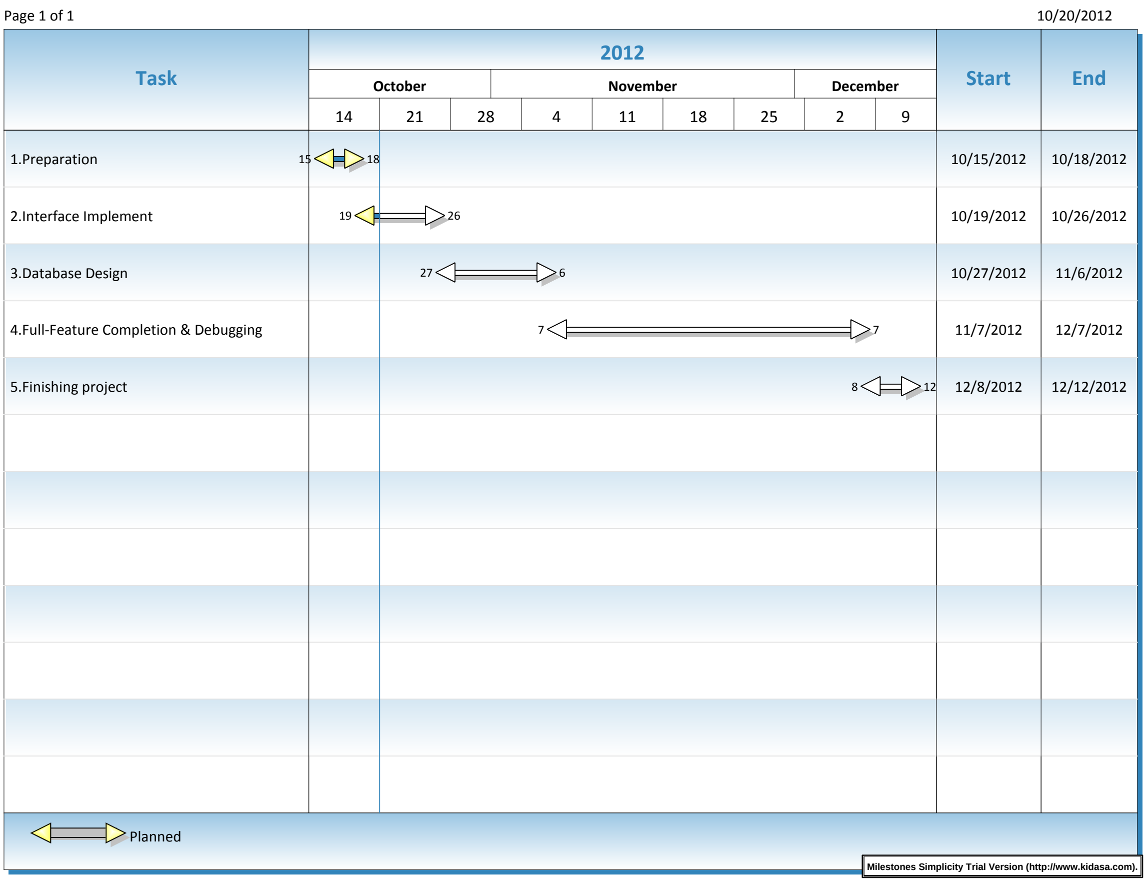

Table 6-1 Plan of Work

Reference

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