Chapter 5
Experimental Study

5.1 Introduction .................................................................................................................. 93
5.2 Experimental aims ....................................................................................................... 93
5.3 Methodology and conduct of the experiment ............................................................. 93
  5.3.1 Participants ............................................................................................................. 93
  5.3.2 Data collection ....................................................................................................... 93
  5.3.3 Experimental setting ............................................................................................. 94
  5.3.4 Experimental procedures ..................................................................................... 94
5.4 An excerpt of student’s transcript for the entire exploration of the BSL System .......... 95
  5.4.1 Introduction Stage ................................................................................................ 97
  5.4.2 Questions Stage ................................................................................................... 98
  5.4.3 Problem-Solving Stage ...................................................................................... 103
5.5 Conclusions ............................................................................................................... 110

Figure 5.1: Sequence of events for the treatment session .................................................... 96
Figure 5.2: Causal effects of the manipulation of *Body Force* on B graph .......................... 97
Figure 5.3: S5’s predicted solution for Task 1 (increase Depth of Submergence) ............... 99
Figure 5.4: S5’s solutions for the variable Shape (Cone, Sphere, and Slanted Cylinder) relative to the starting block and each other ............................................................. 100
Figure 5.5: S5’s predicted solution for Task F2 (Size) ......................................................... 102
Figure 5.6: S5’s predicted solution for Task F5.1 (Increase Width of Body in a floating situation) ......................................................................................................................... 103
Figure 5.7: S5’s manipulation of variables for sinking situation (exploration with immediate and direct feedback) ...................................................................................... 104
Figure 5.8: S5’s answers for sinking situations in worksheet ............................................ 106
Figure 5.9: S5’s solution path for problem P1 (sinking situation only) ............................... 107
Figure 5.10: S5’s solution path for problem P4 (sinking and floating situation) ................. 109
Figure 5.11: S5’s answers for floating situation in worksheet .......................................... 111

Table 5.1: Allocation of excerpts ......................................................................................... 95
Chapter 5

Experimental Study

5.1 Introduction
As mentioned in Chapter 4, an experimental study was conducted, using the BSL System and its supplementary materials that are described later in this chapter. This chapter describes the aims of the experiment as well as its methodology and conduct. An excerpt of a transcript for an experimental session is presented to exemplify how the experiment was carried out.

5.2 Experimental aims
The experimental study aims to investigate students’ usage of the given Articulation-cum-Reflection tool by examining what they articulate and how they articulate during the problem-solving process. It also aims to provide insight into students’ reasoning about buoyancy by examining their causal explanatory model. Their causal explanatory model can help shed some light on the intermediate states or operators in the solution space. Lastly, it is the interest of this research to determine if the pedagogy, Articulation-cum-Reflection, could effect some form of learning and foster a better understanding of buoyancy. Details of the analysis of findings are discussed in Chapters 6, 7 and 8 of this thesis.

5.3 Methodology and conduct of the experiment
5.3.1 Participants
It is imperative that participants have prior formal knowledge of density and equilibrium of forces though a formal instruction in buoyancy is not necessary. This is due to the fact that the Questions Stage of the system aims to uncover students’ buoyancy-related conception. However, in this experiment, all the nine participants were final year undergraduate engineering students who have been taught buoyancy during their secondary school days. The English language is not their first language.

5.3.2 Data collection
The three methods of data collection employed throughout students’ entire exploration are audio-tape, to record their thinking aloud protocols, video-tape to capture students’ screen-displayed graphs, and log-files to trace the history of students’ interactions with the system. All the audio-taped data were transcribed while only two of the video-taped sessions were analysed.
5.3.3 Experimental setting
The research design here is a form of observational case study where detailed examination is conducted on every student’s actions and articulation while interacting with a series of tasks in the BSL System. On the average, each experimental session lasted for about two and a half hours.

5.3.4 Experimental procedures
i. Materials
The instruments used for this experiment were the BSL System, a program in Asymetric Toolbook 4.0 which was designed and developed by the researcher, accompanied by a worksheet, and a glossary of relevant terms.

Worksheet
The worksheet which was only used in the Problem-Solving Stage of the system is shown in Appendix H. It consists of three tasks. Task 1 is exploring and observing the causal relationships between several variables and BSL. The variables explored here have been mentioned in Section 4.2.3 (iii). They are Density of Body, Density of Liquid, Width of Body, Height of Body, and Immersed Volume (for sinking situations only). In Task 2, students are requested to fill in the relationships between the variables and BSL for the sinking scenario. These recorded relationships are then used for solving subsequent problems. In Task 3, students have to fill in the causal effects of the first four variables on BSL for the floating scenario. These causal relationships have to be inferred from the observation of generated graphs.

Glossary
The glossary which consists of definitions of terms used in the system is found in Appendix I. The terms listed are: no cause and effect relationship, depth of submergence, density, same material, volume of immersion, liquid column, target graph, matched graph, real situation and unreal situation.

ii. Role of the experimenter
The experimenter informed the students of the aims of the system and also gave a general overview of the system prior to their exploration. The main role of the experimenter was as a facilitator who prompted the students to justify their predicted solutions and articulate their thoughts.
iii. Treatment session

Before exploring the system, students were informed of its three stages: Introduction Stage, Questions Stage, and Problem-Solving Stage. The procedures for the treatment session are illustrated in Figure 5.1. Notably, they are similar to the functionality of the system which has been discussed in Chapter 4 except for the inclusion of the prescribed tasks in the worksheet. Task 1 of the worksheet required the students to explore the first part of the Problem-Solving Stage where the variables in the Variables Menu were manipulated and the effects on the heading of BSL pointers were observed. This was followed by filling up the causal relationships for the sinking domain in the worksheet. These causal relationships were subsequently used for predicting the solutions for the six ensuing problems. For Task 3 of the worksheet, students were required to fill in the causal relationships for the floating domain. Unlike Task 1, this task was not straightforward and could not be obtained through mere observation but had to be inferred from the results of the experiments for modified real problems.

5.4 An excerpt of student’s transcript for the entire exploration of the BSL System

The transcript for the experimental session with Student S5 is selected to exemplify the conduct of the experiment. Excerpts of the transcript for similar tasks are omitted. Part of the transcript is presented later in this chapter while the rest of the transcript is shown in Appendix J. Table 5.1 lists the tasks whose excerpts will be presented in this chapter or in Appendix J.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Task Chapter 5</th>
<th>Task Appendix J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction Stage</td>
<td>Page 1: Objects</td>
<td>Page 4: String Force</td>
</tr>
<tr>
<td></td>
<td>Page 2: Definitions</td>
<td>Page 5: Liquid Force</td>
</tr>
<tr>
<td></td>
<td>Page 3: Body Force</td>
<td></td>
</tr>
<tr>
<td>Questions Stage (Sinking Domain)</td>
<td>Task 1: Depth of Submergence (2-Dimensional graphs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Task 7: Shape (1-Dimensional graphs)</td>
<td>Task 2: State</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 3: Condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 4: Density of Body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 5: Volume of Body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 6: Volume of Immersion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 8: Volume of Liquid Column</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task 9: Density of Liquid</td>
</tr>
<tr>
<td>Questions Stage (Floating Domain)</td>
<td>Task F2: Size (1-Dimensional graphs)</td>
<td>Task F1: BSL</td>
</tr>
<tr>
<td></td>
<td>Task F5: Volume of Body (2-Dimensional graphs)</td>
<td>Task F3: Density of Body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task F4: Density of Liquid</td>
</tr>
<tr>
<td>Problem-Solving Stage (Sinking only)</td>
<td>Problem P1</td>
<td>Problems P2, P3</td>
</tr>
<tr>
<td>Problem-Solving Stage (Sinking and Floating situations)</td>
<td>Problem P4</td>
<td>Problems P5, P6</td>
</tr>
</tbody>
</table>

Table 5.1: Allocation of excerpts
Figure 5.1: Sequence of events for the treatment session
Note:
Italics indicates system-student interactions, experimenter’s relevant actions, or name of button.
Bold italics in brackets indicates our comments.

5.4.1 Introduction Stage

Introduction
E: Type in your name
S5: My full name?
E: Yea
S5: …typed his name in request dialog box...
E: My system has three parts: first part is the introduction; second part is the questions; and third part is the problem solving. For the introduction, you will be introduced to the objects in the model, the definition of three forces, and manipulation of the forces
E: I will always ask the question why. Use your common-sense reasoning… and when thinking, speak out loud

Page 1: Objects
S5: …viewed screen with model containing three objects: Body, String, and Liquid as shown in Figure 4.3a

Page 2: Definition
E: See if you have any problem with definitions of the forces. They are all phrased in layman’s terms
S5: …viewed screen with equilibrium of forces model (Figure 4.4) with definitions of three forces listed in Table 4.2.
S5: No problem

Page 3: Body Force
E: Click on the button Speed of Animation
S5: …clicked on button Speed of Animation….selected the speed (Fast, Medium, Slow)
S5: …clicked on button Animate Arrow….the Arrow B animated from the Body to the origin of a two-dimensional graph, the arrow disappeared and a green ellipse appeared at the head of the arrow (Figure 4.7b)

The rectangle Body flashed
E: What does the flashing tell you?
S5: No
E: It means ‘Click on me’
S5: …clicked on the rectangle Body after it stopped flashing
S5: …dragged the red indicator in slider for amount of change
E: This is amount of change
S5: …on the Body Force
E: You can keep increasing or decreasing it…can press on button Increase or Decrease
S5: Increase
(Screen display is depicted in Figure 5.2a).
E: What do you see
S5: This thing will move down (referring to the green ellipses in the two-dimensional graph)
E: Why?
S5: … because you are increasing the Body Force
E: When this increases, what happens to the graph here?
S5: The graph is going down….increasing the Body Force…moved cursor from Arrow B to graph B
E: If decrease…. ?
S5: Same amount, this will be going up… the same gradient…moved cursor along the slope
S5: …Clicked on button Decrease….
(Screen display is depicts in Figure 5.2b).
E: Remember, for Body Force, if increase in magnitude, the graph will go down, if decrease, the graph will go up.

5.4.2 Questions Stage
Sinking Scenario
Task 1: Depth of Submergence
E: We are going to change the depth of submergence….Why don’t you keep clicking on the button Increase in Depth (of Submergence)….keep clicking if you want to.
S5: …clicked on button Increase Depth of Submergence
Block sank deeper into the Liquid
E: Do you know what you are supposed to do?
S5: No, no idea
E: You are suppose to plot graphs for String Force, Body Force and Liquid Force….just like your normal physics graphs….Whether it is going up, down or constant
S5: All right
E: Click on these to get the graphs (refer to ellipses in the box)
S5: …..clicked on the green ellipse and a graph is automatically plotted
(Screen display is shown in Figure 5.3a).
(Message on display was) ‘Drag the end ellipse if you intend to modify the slope of the graph’
E: …read aloud the message on display….Drag the end ellipse if you intend to modify the slope of the graph….you can only drag up or down and not left or right
E: What do you think will happen to the Body Force? Stay constant, increase or decrease?
E: What are you thinking?
S5: Increase….dragged the green end ellipse
(Screen display is shown in Figure 5.3b).
E: Increase?
S5: Yea, I think should be increase because the deeper you go, the more gravity
S5: Liquid Force…should be this…I use my common-sense, the deeper you go, yea, the more force…
E: What force is that?
S5: Liquid Force…
E: The more Liquid Force, should it be up, down or constant?
S5: Yea….Oh yea…Liquid Force
S5: …clicked on blue ellipse in box
(L. Graph was automatically generated)
E: What are you thinking?
S5: Constant…dragged blue end ellipse to a position with similar y co-ordinate as the blue starting ellipse
(Screen display is shown in Figure 5.3c).
E: Why constant?
S5: …thinking…
E: What are you thinking?
S5: At this moment is blank…not sure…
E: Use your common-sense
S5: I think should be constant
E: What make you think so? Why do you suddenly change your mind? Just now was increase and now is constant? Why is it that you suddenly change your mind?
S5: Initially, I forgot about the direction of the Liquid Force is upwards, yea….er….when I increase the depth, the force should be remain the same, I think…should remain the same…dropped the blue end ellipse
(Screen display is shown in Figure 5.3c).
E: What about the String Force?
S5: I click this one, yea….clicked on red ellipse in box
S5:…..thinking…
E: Forget about stage 1…it is not related to Stage 1
E: What are you thinking?
S5: I increase this depth….I was thinking if I increase the depth, you need more force to pull it up…that’s why the String Force increase….dragged the red end ellipse.
(Screen display is shown in Figure 5.3d).

Task 7: Shape
Task 7.1: Cone
E: Now, these are the forces for this block, a vertical cylinder. Try the cone
Chapter 5 Experimental Study

S5: … clicked on the button for the cone…
E: Now it is a cone. Read the message below
S5: All right… same volume and same material as starting block
S5: …clicked on green ellipse in box
S5: This one shall be constant….dragged the green ellipse for the cone
S5: …clicked on blue ellipse in box
E: This one.
S5: I think more…dragged the blue ellipse for cone
E: Why is it more?
S5: Bottom area is more….so force exerted is more
S5: …clicked on red ellipse in box
E: String Force now
S5: The String Force is less…dragged the red ellipse for cone
E: Why less?
S5: You already have this….pointing to the L of cone
(Screen display is shown in Figure 5.4a).

Figure 5.4: S5’s solutions for the variable Shape (Cone, Sphere, and Slanted Cylinder) relative to the starting block and each other
Task 7.2: Sphere
S5: … clicked on button Sphere
S5: Sphere
E: How is it compared to the cone and starting block?
S5: clicked on green ellipse in box
S5: This one is probably same (referring to B) …constant….dragged the green ellipse for sphere
S5: This one should be lesser (referring to L) than the other two (referring to two previous L-for starting block and cone) because they are the same…pointing to the circumference of the circle…. yeah
E: What are you focussing on?
S5: To help with the floating (of the sphere), the forces like this…the Liquid Force will bring up further here but then only this area (referring to the lower tip of the sphere) is slightly perpendicular to this (referring to the Liquid Force) but this area (lower left) is not perpendicular so it doesn’t help much
S5: So this one (referring to S) need more
(Screen display is shown in Figure 5.4b).

Task 7.3: Slanted Cylinder
E: Slanted cylinder?
S5: ….laughing away
S5: Hoo….hoo…
S5: …clicked on green ellipse in box
S5: I keep this one constant… dragged the green ellipse for slanted cylinder
E: … so this your rule, yeah?
S5: Hmm… hmm…mapped out the outline of left surface of block to bottom with the mouse
S5: …clicked on blue ellipse in box
E: Now Liquid Force
S5: Liquid Force, yeah?
E: What are you focussing on to help you answer this?
S5: I focus on these three…starting block, cone and sphere…this one (L for the slanted cylinder) should be more than sphere… now I am trying to decide if it is more than original one or less
E: Hmm…hmm
S5: I think it is more than the original one but less than the cone
(Screen display is shown in Figure 5.4c).
E: Why do you think it should be more than the original one? On what criteria do you decide on this answer?
S5: This is what I am trying to think now
E: What are you focussing on to get the answer?
S5: Focussing on the this area (left surface of slanted cylinder) here and this area here (right surface of the slanted cylinder)
E: Oh I see…The slant as well, yeah?
S5: But then it doesn’t make sense
E: Why is it that it doesn’t make sense?
S5: Because you have this force here, it will be balanced by this force (forces on the left are balanced by the forces on the right?)…probably, it is same as the original one….dragged L of slanted cylinder again so that it was of the same position as that of starting block
(Screen display is shown in Figure 5.4d).
E: Hmm… hmmm…why is it the same?
S5: The area of the bottom part
E: …so this is your final decision…. 
S5: Yea…and then this one should be the same (referring to S of slanted cylinder being the same as that of the starting block)…
(Screen display is shown in Figure 5.4e).
Chapter 5 Experimental Study

E: Now the next one
S5: Next one yeah?
S5: Still playing with this one yeah?
E: Oh yes… a few more, quite a lot more

Floating Scenario

Task F2: Size
Task F2.1: Small Block
E: You have a medium sized block here that is floating… what about a small block?….very small and still floating
S5: Small block……Ok…
S5: …clicked on green ellipse in box, followed by dragging it
E: Why should it be there?
S5: The smaller this one, yeah, so the weight should be lesser than the previous one
S5: …clicked on red ellipse in box, followed by dragging it
S5: Why is this one here?
E: This is the String Force
S5: This one (referring to S1, the S in the original state), it is on top of this one (referring to L1 in the L in the original state, Figure 5.5a)…initially….Yeah (made a reference to their relative positions in the previous screens for the sinking scenario)
S5: …clicked on blue ellipse in box, followed by dragging it
E: Why should it be there? The Liquid Force?
S5: The smaller force, see smaller force there
S5: Can I still change this one (the position of S1, the S for original block… feel shouldn’t be at zero)

Figure 5.5: S5’s predicted solution for Task F2 (Size)

E: This one…er….
S5: No
E: No….If you feel that it’s wrong then you can just…. 
S5: Never mind
E: Why is it that just now you have answered why this is less, right?
S5: Yea
(Screen display is shown in Figure 5.5b).

Task F2.1: Big block
Task is similar to Task F2.1 so the excerpt is omitted.
**Task F5: Volume of Body**

**Task F5.1: Width of Body**

E: Next one is the volume of Body. If you manipulate the width of the Body...increase it...how will the force...

S5: ...clicked on green ellipse in box

S5: This one increase...dragged the green end ellipse

E: Why?

S5: Heavier

E: Ok

S5: ...clicked on blue ellipse in box

S5: This one increase...dragged the blue end ellipse

E: Why?

S5: Area

E: Area

S5: Yeah

Figure 5.6: S5’s predicted solution for Task F5.1 (Increase Width of Body in a floating situation)

S5: ...clicked on red ellipse in box

S5: This one should remain constant...dragged the red end ellipse

(Screen display is shown in Figure 5.6a.

E: Why?

S5: Because this one increase...depending on how much force is here (referring to L)...dragged the position of red end ellipse again

(Screen display is shown in Figure 5.6b.

**Task F5.2: Height of Body**

Similar to Task F5.1.

**5.4.3 Problem-Solving Stage**

**Part 1: Sinking Situation**

E: This is problem solving, the last page

E: You have to discover the relationships between the variables and the forces

E: The first scenario that you are going to look at is sinking and there are five variables for sinking, that is Density of Body, Density of Liquid, Width of Body, Height of Body and Immersed Volume of Body

E: The three different kinds of relationships that you can have are: If A increase, B has no change, so there is no change and you don’t need to draw any line. If A decrease, B has no change, so there is no change and you don’t need to draw a line. The second one is A increase and B increase, it is just like directly proportional kind of relationship, same direction...drew out the line with two arrows pointing at the same direction...the same for decrease, yeah? The third
Figure 5.7: S5’s manipulation of variables for sinking situation (exploration with immediate and direct feedback)

one is if it is like inversely proportional kind of relationship, opposite direction…drew out the dotted line with two arrows pointing at opposite directions
S5: Yea
E: If you forget, no line means no relationship; if increase and increase, it is like this…pointing to the instructions in worksheet….if increase and this decrease, it is like this….pointing to the instructions in worksheet
E: Are you ready?
E: You can set to zero by clicking on these (referring to buttons Set to zero)
S5: …manipulated Density of Liquid by dragging the red indicator of slider Density of Liquid , to the right (increase) followed by dragging the red indicator to the zero point of the slider. (Screen display is shown in Figure 5.7a).
E: Why do you choose the Density of Liquid first?
S5: Just trying to…
E: Just playing around first, yeah?
E: Oh want to see if what you believe is correct or not
S5: …manipulated the width of the Body dragging the red indicator of slider Width of Body, to the left (decrease) followed by dragging the red indicator to the zero point of the slider.
(Screen display is shown in Figure 5.7b).
S5: Yeah….laugh….now you know
S5: Now I am trying to see if my reasoning is correct or not
S5: …manipulated the height of the Body dragging the red indicator of slider Width of Body, to the left (decrease) followed by dragging the red indicator to the right (increase), left again, right again and finally, left followed by zero point of slider.
(Screen display is shown in Figure 5.7c).
S5: Ooh…. I am wrong here
S5: …manipulated the immersed volume of the Body dragging the red indicator of slider Width of Body, to the left (decrease) followed by dragging the red indicator to the zero point of the slider.
(Screen display is shown in Figure 5.7d).
E: Are you correct here?
S5: I am correct… I am correct
E: For immersed volume, this is decrease, yeah…because of the negative sign
E: Are you ready to do the relationship?
E: You can manipulate and do…. See whichever is more suitable for you…you can set all to zero first if you want to

Explore causal relationships for variable Density of Body
E: You can set all to zero if you want to
S5: …manipulated Density of Body by dragging the red indicator of slider Density of Body, to the right (increase). (Screen display is shown in Figure 5.7e).
S5: Hmm….hmm. So I have to draw this (in the worksheet) … density with Body Force
E: Body Force is B, and green in colour, String Force is S, and red in colour, Liquid Force is L and blue in colour. See the relationships
S5: Between density and …the forces (in the worksheet)
E: If there is none, don’t draw anything
E: What is the relationship that you see?
S5: Ah….this one yeah…the Body Force and the density
E: What kind of line will you use?
E: If it is directly proportional kind, you use this type of line and if it is inversely proportional kind, you use this type of line. Draw a line from here (variable) to here (BSL)
S5: From here?
S5: This one yeah?
E: What kind of line is it?
S5: Directly proportional
E: String Force?
S5: Ah ha….manipulated the variable…String Force is S yeah?
E: Yea
S5: ….drew the lines…
(Answers in worksheet for sinking situations are shown in Figure 5.8).
E: Any more?
S5: No

Explore the causal relationships for variable Density of Liquid
E: Ok. Density of Liquid
S5: Density of Liquid
S5: …manipulated Density of Liquid by dragging the red indicator of slider Density of Liquid , to the right (increase) , followed by left (decrease)
E: Very confident
S5: Directly proportional is L….drew the relationships in the worksheet…. (Answers are shown in Figure 5.8).
S5: laugh
S5: String Force…

Note:
No line means there is no causal effect relationship

If variable increases/decreases, force increases/decreases (same direction of change)

If variable increases/decreases, force decreases/increases (opposite direction of change)

Figure 5.8: S5’s answers for sinking situations in worksheet

Explore the causal relationship for variable Width of Body
S5: ....manipulated Width of Body by dragging the red indicator of slider Width of Body , to the right (increase)
S5: ...drew the relationships in the worksheet… (Answers are shown in Figure 5.8).

Explore the causal relationship for variable Height of Body
S5: ...manipulated Height of Body by dragging the red indicator of slider Height of Body, to the right (increase)
S5: ..drew the relationships in the worksheet… (Answers are shown in Figure 5.8).
S5: This one I got it wrong….laugh...
E: It is Ok because you used your common-sense reasoning, right?

Explore the causal relationship for variable Immersed Volume of Body
S5: ...manipulated Immersed Volume of Body by dragging the red indicator of slider Immersed Volume of Body , to the right (decrease which is different from the rest of the sliders)
S5: This one is…
E: Decrease because it is negative sign
S5: Decrease…
S5: …drew the relationships in the worksheet…
(Answers are shown in Figure 5.8).

**Sinking: Problem 1**

E: Ok, I am going to create this problem for you. My first problem…S will be down, the *String Force* will decrease.

(Screen display is shown in Figure 5.9a).

E: I am going to call out the variables menu…*click on Variables Menu*…*Variables Menu appeared on the screen*…The *Variables Menu* has five variables and these three are called *pointers* and as you manipulate the variables…one or more, at the same time it might have effect or no effect on these, yeah?

E: What you need to do is you have to manipulate one or more variables so that these pointers, the heading of these pointers coincide with these target graphs (*Figure 4.19*)

S5: Yea. All right

E: This coincides with this target graph (*red pointer with red target graph*), this coincides with this target graph (*blue pointer with blue target graph*) and this coincides with this target graph

![Target graphs for problem P1 (sinking situation only)](image)

E: In order to get that target graph, which variable do you think you will manipulate? You don’t touch the mouse first…just predict

S5: All right

E: See whether your hypothesis is correct or not

S5: I want to get that one constant….*Liquid Force* is constant yeah…*String Force* increasing and *Body Force* decreasing as well…*refer to worksheet*…

E: Which one do you think you will manipulate?

S5: Density….I just want these two so I change the density of the *Body*

E: Test your hypothesis
S5: Yea… manipulated the Density of Body (decrease) so that green pointer coincided with the graph B.
(Screen display is depicted in Figure 5.9b and the matched graphs obtained after pressing button Press Down to Draw Graphs are shown in Figure 5.9c).
E: Yea, you got it, right

**Sinking to Floating Situation**

**Floating: Problem 1**
E: The next one is floating
E: I will create floating situations
E: First one, I am going to increase the Liquid Force so that there will be an unreal situations.
(Screen display is on Figure 5.10a).
E: What is an unreal situation to you?
S5: Hmm…hmm…doesn’t make sense
E: Doesn’t make sense
E: You don’t know what is unreal here?
E: You don’t see anything?
S5: All right it makes sense now…this is unreal because there is no way that this (referring to B) is constant and this (referring to S) decreases, and this (referring to L) increases
E: If I change this to real graphs then you will know why this is unreal
S5: Ah…
E: …click on button Unreal to Real Graphs….
(Screen display is shown in Figure 5.10b).
E: This is a real graph. What is the difference between this and the previous one?
E: This is a real situation
S5: Yea
E: The one you saw just now was unreal
S5: Hmm…hmm
E: In real situation….
S5: Reached equilibrium
E: Actually, all this while it is in equilibrium. Ok, I am going to explain what you are going to do
S5: All right
E: In the same manner, this graph is divided into two parts, part 1 and part 2. Do as you did just now, manipulate the variables in order to get the target graphs
S5: Hmm…hmm
E: After that, keep pressing this and when the graph reaches this critical point, I want you to observe the model
E: For the manipulation, you shouldn’t have any problem any more
S5: Are you sure?
E: Yea
E: You don’t manipulate immersed volume… for floating I don’t want this, yeah?
S5: All right
S5: …manipulated variable….increased Density of Liquid so that the green pointer coincided with first part of the target graph L.
(Screen display is shown in Figure 5.10c).
E: Ok, you got it
E: Keep pressing the button Press Down to Draw Graphs
S5: Press down…
E: Don’t let go….and observe…
S5: …press button Press Down to Draw Graphs…
(Matched graphs generated are shown in Figure 5.10d).
E: Ok, something will happen now….do you see anything happening? (when the matched graphs reached the critical points)
Chapter 5 Experimental Study

Figure 5.10: S5’s solution path for problem P4 (sinking and floating situation)

E: Do you see anything happening to the model?
S5: No.....
E: What changes do you see in the model?
S5: Now it is floating, yeah
E: Yes, floating. Just now, it was sinking for this part....(of the graph).
E: That’s why there is no message, yeah. So it is sinking
E: And this part...
S5: ...it is floating
E: So now, in order to explore the relationships between the variables and the forces, you would have to concentrate on this part of the graph alone and the variables
S5: Hmm...hmm...
E: You have to observe what are the variables you have manipulated and how does the graph look like for floating
E: It won’t be like the previous one where you can play around
S5: Yea
E: What have you manipulated and how do the graphs look like?
E: Don’t look at this...(referring to the sinking part of the graphs)
S5: You want me to give the relationships between this....(referring to Density of Body)
E: Density of Body...do you think at this juncture...can you gather the relationships?
S5: Not yet
E: No, yeah.....so which variable can you answer at this juncture?
E: Which variable have you manipulated?
S5: Density of Liquid

d. Run experiment confirm solution; matched graphs are generated; students can observe a switch form a sinking to a floating situation (condition increase ρ_l or decrease ρ_o)
E: For the sinking section graph...when you manipulated the Density of Liquid, so what does it mean...does it mean that the Density of Liquid changes?
S5: Hmm...hmm
E: What about when it is floating? Does it still change?
S5: No...no
E: Really?
S5: Yea
E: It doesn’t change
S5: It is already floating...the density
E: Do you want to observe the model again?
S5: Hmm...hmm
E: You have to observe the model...reset the manipulation with deletion of matched graphs followed...reinstate the manipulation of variables
E: Keep pressing and observe the model when it is floating
S5: ...keep pressing the button Press Down to Draw Graphs
S5: Hmm...
E: Is there any change in the model?
S5: Hmm...hmm
E: There is...what change do you see?
S5: When it reaches the floating state, the Density of Liquid doesn’t make ...er... change ... remain constant and the Liquid Force remains constant.... so the Density of Liquid doesn’t affect the....
E: But you can see that the Body is floating, yeah?
S5: Hmm...hmm
E: What conclusion will you make for Liquid Force, Body Force and String Force?
S5: Floating?
S5: Density of Liquid....
E: So you concentrate on that part of the graph of floating
E: You want to shift the variables menu away so that you can see better?
S5: Yea
E: No relationship? Directly proportional or inversely proportional?
E: What are you looking at now? What are you focussing on?
S5: This side, yeah...seems like there is no relationship between the density of the Liquid and the three variables.
E: Why do you feel that there is no relationship?
S5:...because all the variables are constant...wrote relationships in the worksheet (Answers are shown in Figure 5.11).

5.5 Conclusions
The BSL System provides a problem-solving environment that promotes active construction of new knowledge that is based on prior knowledge. Its embedded cognitive tool aims to help students articulate their thoughts, facilitate reflection and reasoning during the problem-solving processes. The learning strategies implemented with the system are predict-reflect or predict-test-reflect. One of the main focuses of this research was to analyse students’ problem space between the initial and final states of the problems and the results of the analysis are presented in Chapters 6, 7 and 8 of this thesis.
Note:
No line means there is no causal effect relationship

If variable increases/decreases, force increases/decreases (same direction of change)

If variable increases/decreases, force decreases/increases (opposite direction of change)

Figure 5.11: S5’s answers for floating situation in worksheet