Abstract

The purpose of this learner study is to assess the effectiveness of the Sea Urchin Embryology Virtual Lab. Since the virtual lab is in its early stages of development, we could not analyze the use of it directly. Therefore, in order to get around this setback, we decided to study the learners in the setting of a real biology lab experiment on sea urchin embryology. Our aim was to identify the students’ needs and evaluate the real lab’s strengths and weaknesses in meeting those needs. In doing so, we can then use our findings to inform the design of the virtual lab by recommending the use of features that support learning and enhancing features that don’t.

Our study was composed of three main parts: pre-study interviews (including formal and informal questions and drawings), observations (in the form of note-taking and video taping), and post-study interviews (including formal and informal questions as well as drawings).

Questions

Ease of Use
Q: Is the lab designed and organized to facilitate students’ use? Do students have any difficulty when they are conducting the fertilization experiment?

Features
Q: From students’ perspective, does the lab have some features particularly conducive to their learning and is there anything that could have been improved to enhance students’ learning experience?

Prior Knowledge and Skills
Q: Do the students have any prior knowledge/skills in cell biology (specifically fertilization process)? Are they technically prepared to conduct the fertilization lab experiment? Does the lab provide the ways to compensate for any inadequacy?

Learning
Q: Do the learners know about the objectives of the experiment, both prior and after the experiment? Do the learners demonstrate that they’ve learned what they were supposed to learn?

Virtual Lab
Q: Do the students understand what a virtual lab is? Will they use it if the experiment is available as a virtual lab? Do they have the required technical skills to use a virtual lab?

Methodology

Our methodology consisted of the following:

- **Pre-study**: Interviews (formal and informal), drawing
- **Observations**: video, note-taking
- **Post-study**: Interviews (formal and informal), drawing

Participants

Our study included approximately 30 learner subjects ranging from high school freshmen to high school seniors with different backgrounds in high school biology (some were taking a
biology course this quarter, others had taken a biology course their previous year, and yet others had taken a biology course 2 or 3 years in advance). All in all, none of the students seemed to have an extensive experience with biology lab experiments, as lab experiments tended to take place 2-4 times throughout the school year. We limited the formal interview to four of the students.

**Settings**

- 7 tables, 3-4 students per table, 2 telescopes per table
- Big table in the center with experiment material setup in advance. These included sea urchins, water containers with different water temperatures, beakers, special tools for handling the sea urchins, KCl solution for exciting the urchins and extracting their eggs, syringes for injecting eggs with sperms, and more
- 2 big black-boards
- 1 big screen and a slide-projector
- 3 personnel consisting of:
  - Dr. David Epel, developmental and cell biology scientist from Hopkins Marine Station, whose main role was to give a PowerPoint Presentation on *Historical Views on Reproduction*.
  - Jason Hodin, developmental and invertebrate biology scientist from Hopkins Marine Station, whose main role was conducting and explaining the sea urchin fertilization experiment
  - Pam Miller, high school biology teacher at Monterey Peninsula Unified Schools, who was in charge of running the lab. Pam was the host(ess) and Dr. Epel and Jason were the guests.

**Welcome**

Participants were given a briefing on the lab session. The guests, including our team of researchers, had the chance to introduce themselves and briefly explain the reasons for their visit.

**Pre-study**

Due to a lack of time, our pre-study interviews were limited to a few short questions on the participants’ background in biology and experience with lab experiments. Two of the researchers interviewed four participants formally, and two other researchers casually asked questions from a group of 10 to 13 students. Participants were also asked to draw a quick sketch of their understanding of how fertilization worked.

**Observations**

Actions were recorded on video. Researchers noted written observations about the subjects’ behavior based on:
- questions the participants asked
- answers they provided to the questions asked during the experiment
- types of interactions and collaborations they tended to engage in
- any cues indicating boredom, excitement, understanding or confusion

**Post-study**

The four participants from the pre-study interview were again formally interviewed about their perspectives, understandings and experiences as it related to the entire lab session. Similar questions were also directed towards other students in a casual manner. Additionally, each participant was handed a lab form in which they were asked to draw sketches of different stages of fertilization, based on their observations and knowledge gained throughout the experiment.
Findings

In this section, we have summarized our findings based on a combination of our interview results and observations.

Initial questions revisited

Ease of Use
Q: Is the lab designed and organized to facilitate students’ use? Do students have any difficulty when they are conducting the fertilization experiment?

A: The Biology lab was well designed and organized for the students to take part in the experiment, however, it should be noted that their participation was limited to observing the experiment being conducted by the scientists. The students’ activities were limited to the use of microscopes. While some of them were comfortable working with a microscope, others didn’t know how to manipulate the lens. Some of the students felt the need for a manual to use the microscopes.

Features
Q: From students’ perspective, does the lab have some features particularly conducive to their learning? Is there anything that could have been improved to enhance students’ learning experience?

A: The wet lab setting was a factor in the students’ motivation to conduct and learn from the experiment. The presence of a teacher helped them clarify their doubts. The presentation made by the scientists gave them background information about the experiment and was also a motivating factor. The questions asked by the scientists made the students think and therefore helped in promoting inquiry-based learning. The collaborative learning environment in the lab helped them learn from each other and exchange ideas.

However, the students could not see the fertilization properly because of the sharing of microscopes between students. The actual cell division takes a long time, making it difficult for the students to watch the entire phenomenon. In addition, they could not conduct or watch the results of the experiment more than once.

The fact that they were conducting an experiment on a subject that award-winning scientists have been researching was not emphasized. The knowledge of the authentic nature of the experiment could have further motivated the students.

Prior Knowledge and Skills
Q: Do the students have any prior knowledge/skills in cell biology (specifically fertilization process)? Are they technically prepared to conduct the fertilization lab experiment? Does the lab provide the ways to compensate for any inadequacy?

A: The students had a fair knowledge about cell biology. Though most of them had studied Biology a few quarters or years ago, they were interested in and involved with the experiment. The presentation by Dr. Epel also gave them an overview of the experiment and a historical aspect of reproduction, which helped them in recalling their prior knowledge of the subject.

Learning
Q: Do the learners know about the objectives of the experiment, both prior and after the experiment? Do the learners demonstrate that they’ve learned what they were supposed to learn?

A: Though the students were interested in the experiment, we got the impression that they were not very clear about what they were going to learn from the experiment, and how the knowledge of Sea Urchin embryology would transfer to other organisms and contexts. From the collected drawings of different fertilization stages (drawn by the students after the
experiment was conducted), only about half were accurate. Also, some of the students demonstrated confusion as to which image corresponded to what fertilization stage. While some students preferred to observe the different stages individually and sketch drawings on their own, others tended to be dependent on their peers’ observation results and drawings.

**Virtual Lab**

**Q:** Do the students understand what a virtual lab is? Will they use it if the experiment is available as a virtual lab? Do they have the required technical skills to use a virtual lab?

**A:** Prior to the experiment, none of the students was able to correctly answer Pam’s question “what is a virtual lab”. After the experiment, the students showed awareness of the concept of virtual labs, though not all of them were familiar with the term. They had seen virtual labs on subjects other than Biology too, and liked the interactive nature of virtual labs. Some students anticipated more interaction and involvement in the process of conducting the experiment when using a virtual lab as opposed to the wet lab.

The students said they will be happy if the experiment was available as a virtual lab, and will definitely use it. However, they preferred the real lab over the virtual lab because of the tangibility of the experiment and the collaborative nature of it. They said they would like to use the virtual lab in conjunction with the real lab, either before the experiment as a means to prepare for the procedure or after the experiment for practice purposes.

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**Additional Findings**

**Learners’ profile**

- The students attending the lab were those who were studying biology as well those who had studied biology 1-3 years ago and were studying other subjects this year.
- The students were studying in grades 9 to 12.
- They were attending the lab to see the cell biology experiment, both for learning and fun.
- Most students used the Internet at school or home, and for their personal use as well as finding information for their research, both on biology and other subjects.
- Most students had seen and interacted with a virtual lab.

**Pre-study**

- The students drew diagrams of cell embryology, which revealed that their understanding of embryology was good. They had a fair theoretical knowledge of cell biology.
- Most diagrams were correct though almost all students drew a much bigger egg compared to the sperms.

**Observations**

- The students were curious because it was a new topic and a new experience. Most students were interested and excited, though some were not much interested. They were enthusiastic about the experiment and enjoying it.
- Some students were able to see the fertilization, though most were not able to.
- They were able to see the eggs and sperms with the microscope.
- The students did not participate in the entire experiment. The initial steps were conducted by Jason. Dr. Epel gave a presentation on Sea urchin embryology and the historical aspects of reproduction, which made the students curious and gave them a fair idea of fertilization.
- A series of microscopes were kept with various stages of embryology, and the students saw the stages one after the other.
- Dr. Epel asked questions on cell biology. Some students participated in the Q&A session.
There was a lot of collaboration between students and they were discussing the experiments and asking questions to each other.
If the microscope was kept lit for a long time, it could affect the eggs and sperms.
The students were taking turns to watch the processes as the number of students was more than the microscopes.

Post-study

The students drew the diagrams of various stages in the embryology process. Most diagrams were accurate.
They said they understood the experiment; however, they didn’t know why Sea urchins were being used in the experiment.
They will use a virtual lab if the same experiment is available online.

The students reported the following positive aspects of the experiment:
They preferred the real lab to the virtual lab.
They wanted the presence of a teacher during the experiments so that they can ask for help or clarifications.
A presentation was made on cell biology before the experiment.
They could collaborate with their peers for a better understanding of the experiment.

The students also reported the following shortcomings of the experiment:
They wanted to perform all steps of the experiment.
Some students were not able to see the fertilization process clearly.
The students did not participate in the entire experiment.

Suggestions

1. Collaborative settings for learning
   We found that students thought the collaborative nature was the most enjoyable feature of the real lab experiment. Students replied that they like to share ideas and learn from one another. The collaborative learning is a feature that seems to motivate the students in the real lab.

2. Guidance from experts (scientists)
   Scientist from the Marine Hopkins Station took the role of facilitator in the sea urchin fertilization experiment. They gave introduction to historical background of the development of fertilization so that the students would understand the contextual meaning of this experiment. Scientist tried to give the students a clear focus about the sea urchin experiment.
   The assistance of real scientists seems to motivate the students in asking questions that require deep understanding of biology. The scientists did not just provide the expertise but also tried to guide the students in further scientific inquiry. For instance, prof. Epel asked students to think about a hypothesis during the experiment and then asked how they would test it. Instead of giving answers, they assisted the students in developing their own questions and forming a scientific experiment to test that hypothesis.

3. Teachers role of linking the findings with the curriculum
   The teacher always tried to make sure the all students were on track in the process of the experiment. The students relied on the teacher to inform them of the next step of the process and asked questions about things that were uncertain to them.
   The teacher would link the findings of the experiment to the current high school biology. She provided specific learning goals for the students to focus on so that the students would not get lost.

4. Supporting materials using Multimedia
   Before the experiment, experts used pictures, graphics and video clipping of cell division in their PowerPoint presentation.
   The use of multimedia seems to make the students engaged more in the subject and help them visualize the fertilization process.

5. Authenticity of the lab experiment
Students were able to take part in the experiments that award winning scientists were working on.

The students were not so aware of authenticity of the activity so it would be recommended that this feature is emphasized in the virtual lab.

Appendix

Transcripts of Interviews

Formal (Structured) Interview

Pre-study Questions

<table>
<thead>
<tr>
<th>Learner Profile</th>
</tr>
</thead>
</table>
| **1** What grade are you in? **L1**: 11th grade  
**L2**: 10th grade  
**L3**: 10th grade  
**L4**: 10th grade |

| **2** Do you know about cell biology? **L1**: Yes  
**L2**: Yes  
**L3**: Yes  
**L4**: Yes |

| **3** Do you know how to use computer and the Internet, how to install software? Do you have internet access at home? **L1**: Yes, I know how to use computer and the Internet and access the Internet both at home and in school, but do not know how to install software.  
**L2**: Yes, I know how to use computer and the Internet and have Internet access at home too. I may need help to install Software. |

Post-study Questions

<table>
<thead>
<tr>
<th>Learner’s Experience</th>
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</table>
| **4** How easy it is to use the lab? **L1**: Easy  
**L2**: Not easy  
**L3**: Easy  
**L4**: Easy |

| **5** Do you like the lab settings? Why? **L1**: Yes. It is easy to use  
**L2**: Yes. It is easy to follow and there is help from teachers.  
**CL3**: Yes. Because we can see things first hands-on.  
**L4**: Yes, because it is unique and memorable. |

| **6** Did you experience any difficulties during the experiment? **L1**: No  
**L2**: Yes, have difficulties in adjusting microscope lens  
**L3**: No, because they (the scientists) did most of the lab. We just saw the microscope.  
**L4**: No |

| **7** Do you need or use lab manual or user guide to know how to manipulate the lab equipment? **L1**: Yes  
**L2**: Yes  
**L3**: No  
**L4**: No, they told us how to use it and I |
**Learner's Knowledge**

8. Which is better for learning - to work individually or in a group in the lab? Why?

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>L1: Group. We can exchange ideas</td>
<td>L2: Group. We can learn from each other</td>
</tr>
<tr>
<td>L3: Group. We can talk about the experiments</td>
<td>L4: Groups. Then we can talk about the experiments while doing it.</td>
</tr>
</tbody>
</table>

9. Would you prefer to have help or assistant (teachers, experts, peer students, books) during the lab? (Collaborative Learning)

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<table>
<thead>
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</thead>
<tbody>
<tr>
<td>L1: Yes. I need help</td>
<td>L2: Yes. It is better to have help</td>
</tr>
<tr>
<td>L3: Yes.</td>
<td>L4: Yes. If there wasn’t any teacher or scientists it would be hard.</td>
</tr>
</tbody>
</table>

10. How do you think the learning material should be presented? (words? Graphic? Multimedia so on)

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<table>
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<tbody>
<tr>
<td>L1: Multimedia</td>
<td>L2: Video</td>
</tr>
<tr>
<td>L3 &amp; L4: We use computers in classrooms but it’s mostly for the teachers. Sometimes they use projectors like today to show us some stuff.</td>
<td></td>
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</tbody>
</table>

11. Is there anything that could have been improved to enhance your learning experience?

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<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td>L1: No</td>
<td>L2: No</td>
</tr>
<tr>
<td>L3: Do more things by myself.</td>
<td>L4: I wish we could do more thing by ourselves. The lab was kind of passive.</td>
</tr>
</tbody>
</table>

12. Do you know why sea urchins are being used? (content)

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<tbody>
<tr>
<td>L1: No</td>
<td>L2: Yes. It’s easy to be used.</td>
</tr>
<tr>
<td>L3: Yes. Because its development is something like a larva changing into a butterfly. It’s supposed to be dramatic?</td>
<td>L4: Yes. It’s easy for experiments.</td>
</tr>
</tbody>
</table>

13. Do you know how this lab is related to cell biology in general? (content)

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<thead>
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<tbody>
<tr>
<td>L1: Yes</td>
<td>L2: Yes</td>
</tr>
<tr>
<td>L3: Yes</td>
<td>L4: Um.. we studied it long time ago. We learned fertilization in biology class.</td>
</tr>
</tbody>
</table>

14. Do you know the learning objectives for the lab? Do you know why we are doing in the lab? (learning goals)

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<tbody>
<tr>
<td>L1: A little bit</td>
<td>L2: Not at all</td>
</tr>
<tr>
<td>L3: Yes. See the sea urchin fertilization.</td>
<td>L4: Yes. See the sea urchin fertilization.</td>
</tr>
</tbody>
</table>

15. Did you think the learning material is easy or difficult? (content)

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>L1: Easy</td>
<td>L2: Easy</td>
</tr>
<tr>
<td>L3: Easy</td>
<td>L4: Easy</td>
</tr>
</tbody>
</table>

16. To develop scientific reasoning, you may need to do the same lab again and again but using different variables, which one would you prefer to do:

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<tbody>
<tr>
<td>L1: Repeat the real labs</td>
<td>L2: Repeat the real labs</td>
</tr>
<tr>
<td>L3: I like the real lab.</td>
<td>L4: Only after I had the real lab experience first. Then I think I’ll use it (the virtual lab). Because I wouldn’t know what to do.</td>
</tr>
</tbody>
</table>

17. Are you satisfied with the lab?

<p>| | |</p>
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</thead>
<tbody>
<tr>
<td>L1: Yes</td>
<td>L2: Yes</td>
</tr>
</tbody>
</table>

18. Do you think you learned a lot from this lab

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</thead>
<tbody>
<tr>
<td>L1: Yes</td>
<td></td>
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</tbody>
</table>

experiment?  
L2: Yes  
L3: Yes, because they (scientists & the teacher) showed us a lot of things and explained it to us.  
L4: We already learned these things in biology class two years ago. But using sea urchins were interesting.

| 19 | Do you have any more questions about the lab? | L1: No  
L2: No  
L3: No  
L4: No |
| 20 | Anything you didn’t understand about the lab | L1: No  
L2: No  
L3: No  
L4: No |

Informal (Unstructured) Interview Matrix

<table>
<thead>
<tr>
<th>Learners</th>
<th>Questions</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>L7</th>
<th>L8</th>
<th>L9</th>
<th>L10</th>
<th>L11</th>
<th>L12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you use the Internet at school or at home?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>Do you use the Internet for studying biology/other subjects?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>3</td>
<td>Was the information on the Websites in the form of text and graphics?</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>4</td>
<td>Was the information on the Websites interactive?</td>
<td>N</td>
<td>NA</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>NA</td>
<td>N</td>
<td>Y</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>5</td>
<td>Did you see the fertilization process?</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>6</td>
<td>Did you see the eggs and sperms?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>7</td>
<td>Do you prefer the real lab over the virtual lab?</td>
<td>NA</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
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<td>Y</td>
<td>N</td>
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<td>8</td>
<td>Is it a good idea to have this experiment as a virtual lab?</td>
<td>NA</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
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<td>9</td>
<td>Do you know why Sea Urchins are being used for the experiment?</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
<td>10</td>
<td>Have you done any cell biology</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<td>related labs before?</td>
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</tr>
<tr>
<td>11 Do you enjoy lab experiments?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
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</tr>
<tr>
<td>12 Would you have preferred to have the experiments more often?</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>13 Do you know what a Virtual Lab is?</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>Y</td>
<td>NA</td>
<td>N</td>
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**Drawings**

<table>
<thead>
<tr>
<th>Learner 1</th>
<th>Learner 2</th>
<th>Learner 3</th>
<th>Learner 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Pre-study" /></td>
<td><img src="image2" alt="Post-study" /></td>
<td><img src="image3" alt="Pre-study" /></td>
<td><img src="image4" alt="Post-study" /></td>
</tr>
</tbody>
</table>