Report: Student Process and Questionnaire

Process Followed by Students

Students accessed the GeoGebra simulation via the dedicated web portal at https://www.simulabsphysics.com/heat-waves/egwjyhee, which opened directly in their browser. Before beginning the structured activities, they familiarized themselves with the interface, exploring sliders to adjust mass, spring properties, and time controls, as well as buttons to start, stop, and reset animations. Once comfortable with the environment, they proceeded through a sequence of three main activities designed to reinforce concepts of simple harmonic motion.

In Activity 1, students selected a set of predefined masses and used the simulation to measure the corresponding elongation of the spring. They recorded each mass–elongation pair in a preformatted table, ensuring precise readings by pausing the animation when the system reached equilibrium.

During Activity 2, participants used the built-in stopwatch to time ten full oscillations of the mass–spring system. From these measurements, they calculated the average period *T*. Recognizing that the spring itself contributes to the system's inertia, they then employed the corrected period formula. $T = \sqrt{\frac{m+\frac{m_{spring}}{3}}{k}}$

to solve for the elastic constant *k*. By performing this procedure across several test masses—and incorporating the spring's effective mass—they consistently obtained values of *k* within 1 % of the theoretical prediction, demonstrating both the accuracy of the simulation and the importance of accounting for the spring's mass.

In Activity 3, students explored how physical properties of the spring influence its behavior. They varied the spring material (e.g., steel, copper), wire gauge, coil diameter, and the number of turns using dedicated controls. For each configuration, they noted the resulting changes in the calculated constant k, discussing the direction and magnitude of variation.

Finally, after completing the interactive tasks, all students filled out a detailed questionnaire reflecting on their observations, calculations, and overall experience with the simulation.

Questionnaire Administered

1. What value of gravitational acceleration did you determine for Earth?

2. What value of gravitational acceleration did you determine for the Moon?

3. What value of gravitational acceleration did you determine for planet F?

4. What percentage error did you calculate between the theoretical and measured gravity on Earth?

5. What percentage error did you calculate between the theoretical and measured gravity on the Moon?

6. What value of the spring constant k did you obtain using the oscillation period?

7. What value of the spring constant k did you obtain when varying the mass of the spring itself?

8. What percentage error did you calculate between the measured value of k and the theoretical value?

9. What percentage error did you calculate between the calculated k (considering spring mass) and the theoretical value?

10. How did the spring constant change when varying the spring material? [Figure 2]

11. How did changing the coil diameter affect the value of the spring constant? [Figure 3]

12. How did varying the wire gauge influence the spring constant? [Figure 4]

13. How did changing the number of turns affect the spring constant? [Figure 5]

Data collection

The data collected from 1 to 9 are found in an .xlsx document called "Study.xlsx" uploaded to this same repository, however they can be seen in figure 1.

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 9
Student	**Response**	**Response**	**Response**	**Response**	**Response**	**Response**	**Response**	**Response**	**Response**
1	9,82	1,65	11,9	0,1	1,9	21,038	20,528	2,6	4,98
2	9,71	1,72	11,2	1,0	6,2	22,688	21,2	5,0	1,87
3	9,75	1,75	13	0,6	8,0	20,528	20,219	5,0	6,41
4	9,92	1,8	12,02	1,1	11,1	22,49	21,552	4,1	0,24
5	9,7	1,8	11,35	1,1	11,1	23,212	21,036	7,4	2,63
6	9,67	1,9	12,01	1,4	17,3	24,539	22,12	13,6	2,38
7	9,66	1,65	11,85	1,5	1,9	21,56	21,037	0,2	2,63
8	9,62	1,67	11,72	1,9	3,1	22,117	21,483	2,4	0,56
9	9,81	1,65	11,6	0,0	1,9	20,521	21,682	5,0	0,36
10	9,8	1,71	11,52	0,1	5,6	21,038	22,656	2,6	4,87
11	9,71	1,75	11,8	1,0	8,0	20,5	21,04	5,1	2,61
12	9,5	1,55	12,05	3,2	4,3	24,539	20,525	13,6	5,00
13	9,85	1,66	12,07	0,4	2,5	23,897	22,653	10,6	4,85
14	9,72	1,73	11,32	0,9	6,8	21,568	21,5	0,2	0,49
15	9,7	1,6	11,9	1,1	1,2	21,591	21,05	0,1	2,57
16	9,42	1,74	11,76	4,0	7,4	21,0386	24,215	2,6	12,08
17	9,86	1,52	11,64	0,5	6,2	22,688	23,889	5,0	10,57
18	9,63	1,75	11,34	1,8	8,0	23,671	21,61	9,6	0,02
19	9,53	1,63	11,23	2,9	0,6	21,754	21,566	0,7	0,18
20	9,82	1,65	11,5	0,1	1,9	21,567	24,535	0,2	13,56
21	9,75	1,67	12,03	0,6	3,1	21,567	21,523	0,2	0,38
22	9,71	1,72	11,56	1,0	6,2	21,038	21,6	2,6	0,02
Average	**9,71**	**1,69**	**11,74**	**1,2**	**5,6**	**22,052**	**21,783**	**4,5**	**3,60**

Figure 1: Student response data for Questions 1–9

The data for questions 10 to 13 are found in circular diagrams corresponding to figures 2, 3, 4 and 5.

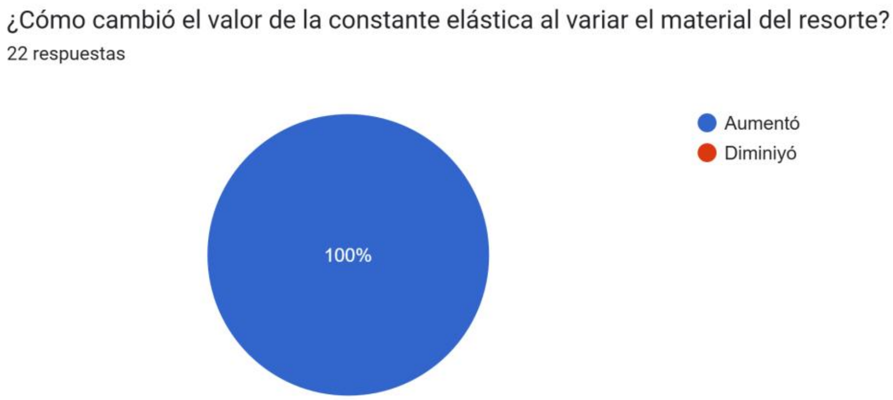

Figure 2: Pie chart showing student answers to “How did the spring constant change when varying the spring material?”; 100 % of students reported an increase.

Figure 3: Pie chart of responses to “How did changing the coil diameter affect the spring constant?”; 90.9 % observed a decrease, 9.1 % an increase.

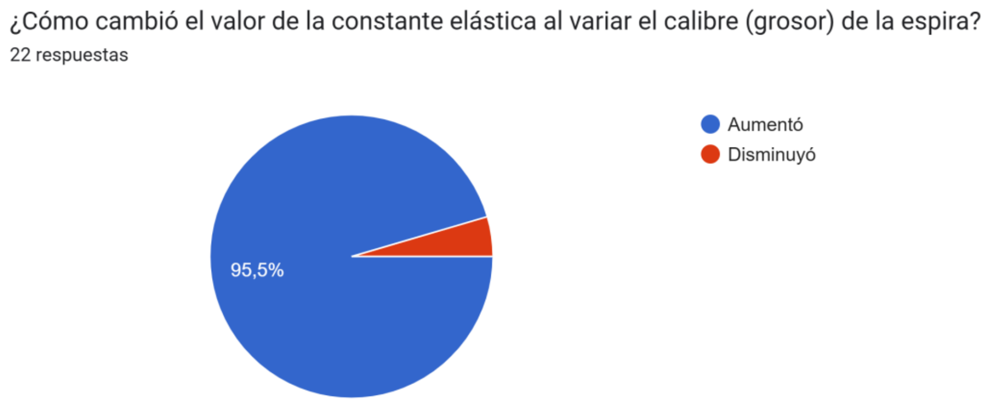

Figure 4: Pie chart of responses to “How did varying the wire gauge (thickness) influence the spring constant?” ; 95.5 % reported an increase, 4.5 % a decrease.

Figure 5: Pie chart of responses to “How did changing the number of turns affect the spring constant?”; 86.4 % observed a decrease, 13.6 % an increase.

Simulation Access

To enable full replication and further use of our tool, the complete GeoGebra simulation is available online and fully editable. Users can:

- The GeoGebra simulation can be accessed and run directly on our website at **https://www.simulabsphysics.com/heat-waves/egwjyhee**
- For more detailed information, to request the full editable version, or for any technical assistance, please contact the corresponding author at: franciscoracedo@mail.uniatlantico.edu.co
- Review all GeoGebra scripting and configuration details in Appendix A of this article, where the full code and setup commands are provided.