Enhancing Physics Learning Through Playing Educational Games

(Case Study: Physics Equation-Based Card Game)

Honors Distinction Project

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Contents

This paper Introduces a physics equation-based card game that is predicted to enhance physics learning outcomes for physics juniors and seniors at Roanoke college. The game is an example on educational games that are used in informal learning styles. The effectiveness of the card game has been measured using the results of 15 pre- and post-assessment questions. It was found that this educational card game does in fact help students make better connections between variables in physics equations. This paper examines the ability of physics students to answer assessment questions correctly after playing the game. It farther discusses the impact of playing to win on making the learning experience more enjoyable, thus leading to better outcomes.

Introduction

Educational games have been proven in literature to enhance the learning experience of children in kindergarten and primary school. The Philosopher and pedagogue Fredrich W. Froebel emphasized the importance of play in the development of early learning experiences for children. (Encyclopedia Britannica 2021) In a school setting, such games and activities increase the psychological motivation of students and thus enhances their comprehension skills.

It is usually argued that intelligence is the reason behind good or bad performance in school and is the dividing line between smart students and not-so-smart students. However, learning does not necessarily have to do with the intelligence or intellectual abilities of the student. It is mostly dependent on the interest students have and show towards the material taught in class. The motivation behind this experiment is the belief that interest rather than intelligence is what pushes students to work harder to comprehend the material which will eventually lead to better performance. Therefore, to improve student performance, more efforts should be focused on increasing the interest of students to make them more passionate about learning.

It is predicted that one of the best ways to make learning and studying more enjoyable is by challenging students through playing educational games that put them in a win and a competition mindset. As a result, learning is accompanied with joy and internal motivation. The importance of the competition mindset is that it challenges students to improve their performance and prove their ability to win a game or an activity. Therefore, joy is not the direct reason for performance enhancement. It is rather the curiosity and questions that students raise throughout the game that make them interested in finding an answer. As mentioned earlier, once the student is interested enough in seeking answers, the learning experience turn into its most effective form.

Similarly, enjoying the learning experience is not only beneficial for children but also for college students and adults in higher education. (Kutty et al. 311) Therefore, the idea of engaging college students in educational games was born. The objective of this experiment is to merge physics education research with game-based learning to measure the effectiveness of playing a physics card game on physics seniors and juniors at Roanoke college as a case study. **The prediction is that playing physics educational games increases motivation and curiosity of physics students, thus enhances the ability of those students to make connection between different constants and variables.**

It is important to notice that informal game-based learning is nothing to new to education since it has been widely used in outreach activities. Moreover, incorporating this form of education into college classes does in no way replace the role of the teacher or professor in the classroom. Educational games and activities only serve the purpose of enhancing information retainment for students rather than

teaching them concepts from scratch. Complimenting formal classroom teaching is the main purpose of this card game as it adds another aspect to learning that is not exclusive to listening, taking notes, and answering questions.

Methods

The card game was constructed by collecting equations from different physics classes that Roanoke College students typically take for their physics major requirements. Two groups were chosen based the number of years of physics experience they have had so far. Seniors and juniors were the two test groups because they have at least two years of physics experience and have been introduced to most/all of the equations included in the game. A total of 9 RC physics students have participated.

The experiment started with students answering 15 pre-assessment multiple choice questions on google forms[1]. They did not have access to the answers in this stage because they had to answer the same questions again after playing. For the sake of fairness, students played with their particular class group. In other words, seniors played in a group of seniors only and Juniors played with other juniors only. Each of the groups played for a period of 40 minutes.

One variable from each equation has been omitted to construct equations with missing variables. Such variables were placed on the players' cards instead. The cards carrying equations were introduced as the main cards whereas the cards that players play with, were labeled as the variable cards because they include the missing variables[2]. The participants had 5 variable cards each and were allowed to draw one main card when their turn comes.

Since the participants were not expected to have any of the main-card formulas memorized in advance, a cheat sheet was included in the package. Whenever students had difficulty remembering what the missing variable was, they looked at the cheat sheet to find out. Then they checked their variable cards to see if they happen to have that particular missing variable. If they do have it, they take the main card as a score and play a second time. If they do not have the variable, they draw another variable from a separate pile and check if it is the correct one. After drawing a new variable, if it is still not the correct one, the turn moves to the next person.

Once the game was over, the participants filled out the same exact 15 post-assessment questions on google forms. This step was crucial to the experiment because it was the decisive factor for the effectiveness of the card game. The results of the post-assessment questions were compared to their counterparts in the pre-assessment stage. At the end, each of the nine participants received a $20-gift card of their choice as appreciation for their time and participation.

[1] See Appendix A

[2] See Appendix C

Data and Results Tables

1. **Seniors Table (5 participants)**

Question #	Right Answer	Percentage Before Game	Percentage After Game	Percentage up or down	Results
1	Radius	60%	60%	0%	No change
2	More density	100%	100%	0%	No change
3	Inversely proportional	40%	60%	50% up	Better
4	Capacitors in series	20%	40%	100% up	Better
5	Velocity and area	60%	40%	50% down	Worse
6	Larger magnetic field	80%	80%	0%	No change
7	Time	40%	60%	50% up	Better
8	Less pressure	80%	80%	0%	No change
9	Yes	0%	40%	4000% up	Better
10	Both acceleration and velocity	60%	80%	33.3% up	Better
11	Cosine angle	80%	80%	0%	No change
12	Inversely proportional	40%	60%	50% up	Better
13	Zero	40%	80%	100% up	Better
14	Vector	60%	60%	0%	No change
15	Larger moment of inertia	40%	100%	150% up	Better

2. **Juniors Table (4 participants)**

Question #	Right Answer	Percentage Before Game	Percentage After Game	Percentage up or down	Results
1	Radius	100%	100%	0%	No change
2	More density	25%	100%	300% up	Better
3	Inversely proportional	75%	75%	0%	No change
4	Capacitors in series	25%	50%	100% up	Better
5	Velocity and area	0%	25%	2500% up	Better
6	Larger magnetic field	100%	75%	25% down	Worse
7	Time	25%	100%	300% up	Better
8	Less pressure	75%	75%	0%	No change
9	Yes	25%	75%	200% up	Better
10	Both acceleration and velocity	100%	100%	0%	No change
11	Cosine angle	75%	100%	33.3% up	Better
12	Inversely proportional	25%	75%	200% up	Better
13	Zero	0%	100%	10000% up	Better
14	Vector	25%	100%	300% up	Better
15	Larger moment of inertia	75%	50%	33.3% down	Worse

Sample Calculation

Percent difference[3]:

$$\left|\frac{\boldsymbol{Percentage\ after\ game - Percentage\ before\ game}}{\boldsymbol{Percentage\ before\ game}}\right| \boldsymbol{x\ 100\%}$$

$$\left|\frac{\boldsymbol{60\% - 40\%}}{\boldsymbol{40\%}}\right| \boldsymbol{x\ 100\% = 50\%}$$ [4]

Discussion

From the previous results, the following percentages have been found:

Class	Total Number of Questions	Number of Improved Questions	Percentage Range	Number of Deteriorated Questions	Percentage Range	Number of No change Questions	Percentage Range
Seniors	**15**	**8**	**33.3% - 4000%**	**1**	**50%**	**6**	**0%**
Juniors	**15**	**9**	**33.3% - 10000%**	**2**	**25% - 33.3%**	**4**	**0%**

When Roanoke College students engaged with each other in this educational card game, the results showed to be effective for the majority of the assessment questions (8 questions for seniors and 9 questions for juniors). However, this game was not as helpful for some of the questions where there was either no change or negative change in the answers after playing the game. Since those questions were not as many compared to the positive change questions, the deterioration in some answers could be referred to one or two students doubting their first answer and changing it to the wrong one instead.

As predicted, the examined card game had its own strengths and shortcomings. On one hand, according to most participants, the game was easy to play and very enjoyable and almost a 100% of them said they would play the game again[5]. The questions that displayed positive change were higher than both the negative-change and the no-change questions, even though some students did have more knowledge than others from classes they have previously taken.

On the other hand, the results of this game were only measured on a short-time scale (40 minutes) so there was no way to tell if the students would retain the same information a week or a month after playing the game. It is important to notice that the game tests the students' abilities to make connections between variables rather than memorizing them even though it could be helpful for the latter as well.

This game could have been played in different ways but only one way was put to test. For example, the colors of variable cards were only included for the aesthetic presentation, but participants suggested that different colors could represent different points based on the equation difficulty level. There were also some suggestions on playing the game in a way where participants can steal each other's cards for winning purposes. Therefore, more cohesive results could have been observed if the game was tested in

[3] This formula does not work if the start value is 0, therefore all zero values were replaced by 1 and rounded to the nearest ones.

[4] Using number of players instead of percentages would give the same results as well.

[5] See Appendix B

different ways and played over longer periods of time or over several times throughout the semester. Thus, the future outlook for this game is to be used in different physics classes to improve information retainment for physics students.

Conclusion

Educational games and interactive activities are some of the most enjoyable ways to learn and interact with the material taught in class. The objective of this experiment was to measure the effectiveness of playing a physics card game on information retainment for physics seniors and juniors at Roanoke college. The card game presented in this paper has proven that playing physics educational games increases motivation and curiosity of physics students, thus enhances the ability of such students to make connection between different constants and variables. This conclusion could be extended to students from different class grades and could be applied to other fields in physics and general sciences.

References

1. Kutty, Asha & Joy, Manu. “Game- Based learning- A Solution for Current Issues in Higher Education? *Seventeenth AIMS International Conference on Management*, pp. 306-313.

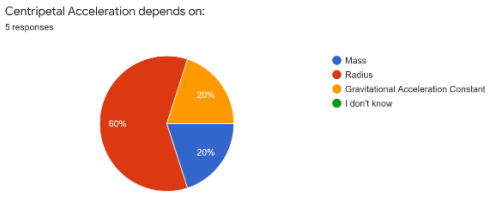
2. Curtis, Stanley James. "Friedrich Froebel". Encyclopedia Britannica, 17 Apr. 2021, https://www.britannica.com/biography/Friedrich-Froebel.

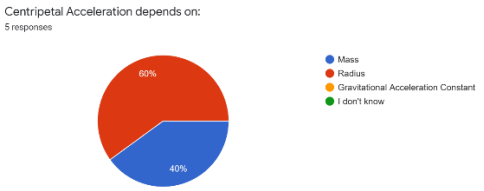
3. Equations included in the card game were collected from the following physics classes: *Newtonian Mechanics, Modern Physics, Introductory and advanced Electricity and Magnetism, Fluid Mechanics, Quantum Mechanics, Thermal Physics.*

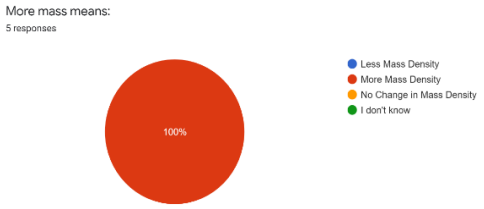
Appendices:

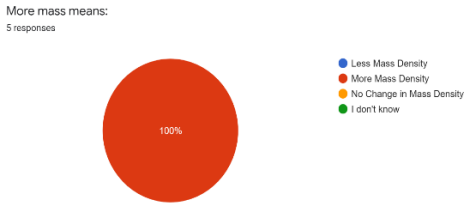
Appendix A: Assessment questions and answers before and after playing the game:

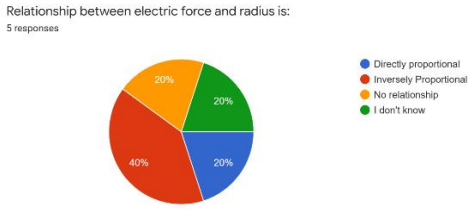
Graphs for Senior Results (left graph: Before playing the game, right graph: After playing the game)

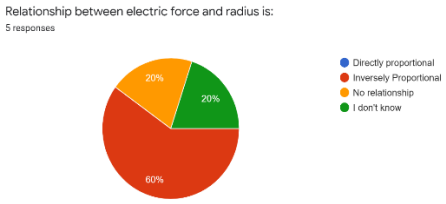


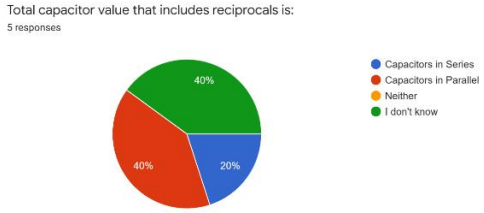


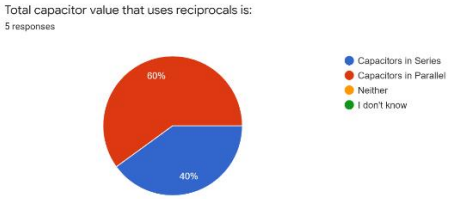


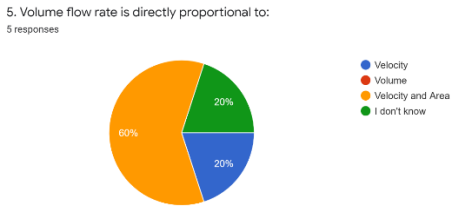


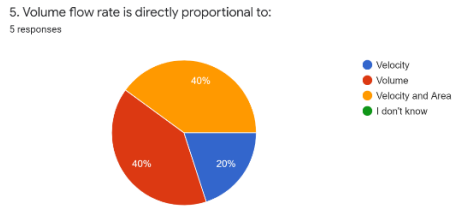






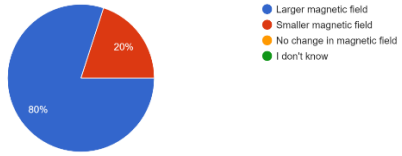






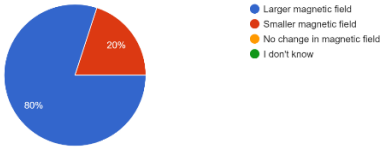
6. Larger Current means:

5 responses



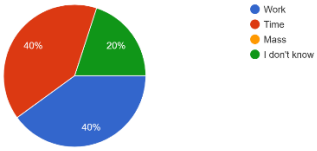
6. Larger Current means:

5 responses



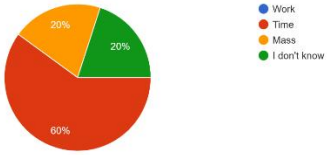
7. Power depends on Energy and:

5 responses



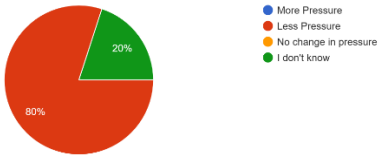
7. Power depends on Energy and:

5 responses



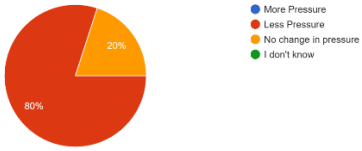
8. Larger Area means:

5 responses



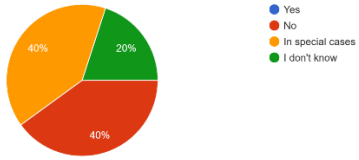
8. Larger Area means:

5 responses



9. Does the speed of sound depend on temperature?

5 responses



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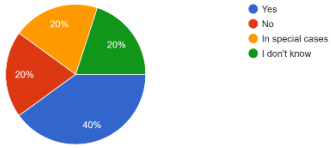
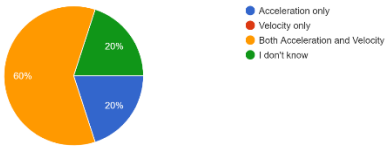


10. Projectile motion depends on:

5 responses



10. Projectile motion depends on:

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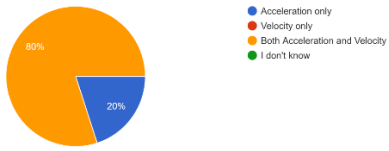
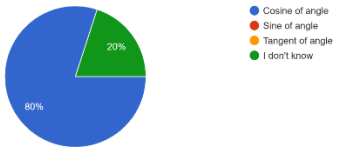


11. Dot product gives magnitudes multiplied by:

5 responses



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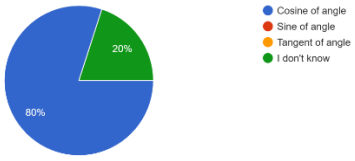
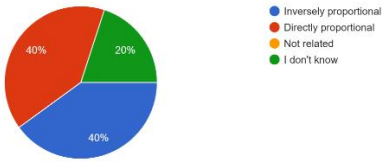
5 responses



12. Linear Frequency and time period are:

5 responses



12. Frequency and time period are:

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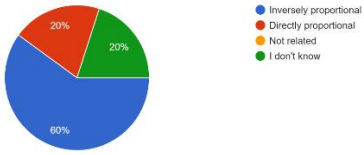
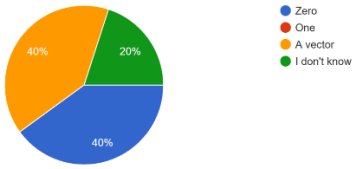


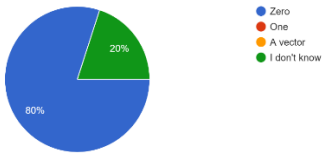
13. Divergence of a curl always gives a:

5 responses



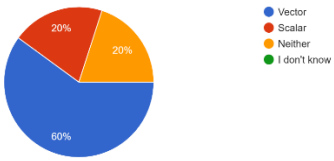
13. Divergence of a curl always gives a:

5 responses



14. Del is a:

5 responses



14. Del is a:

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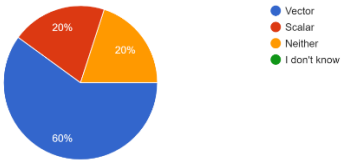
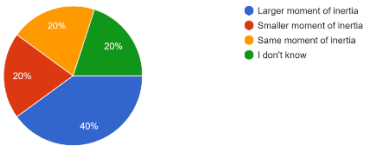


15. Larger mass means:

5 responses



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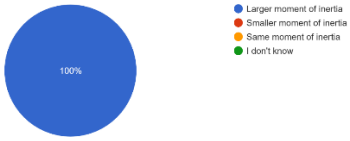
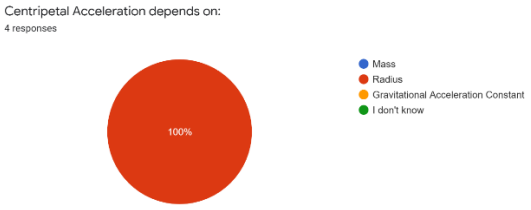
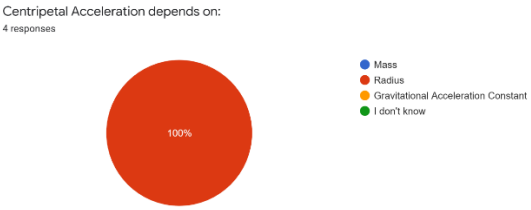
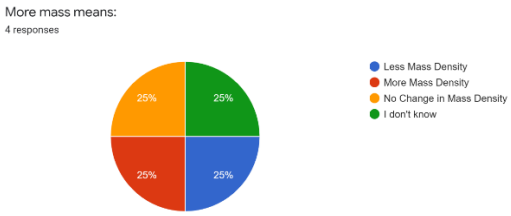
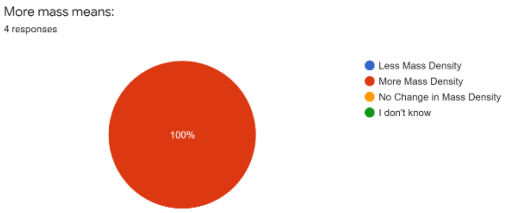


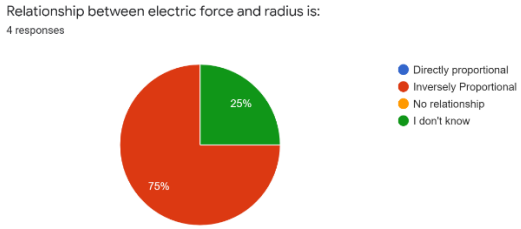
Graphs for Junior Results (Left: Before playing the game, Right: After playing the game)

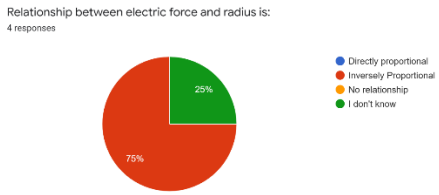


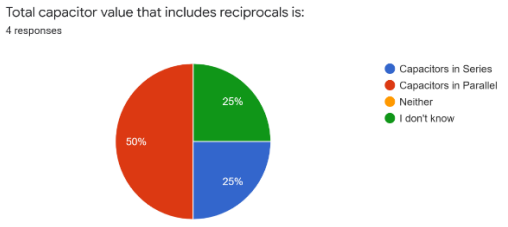


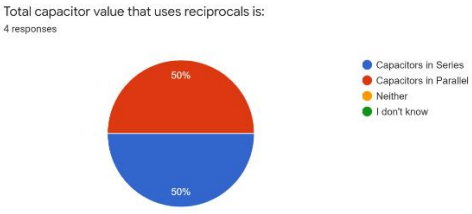


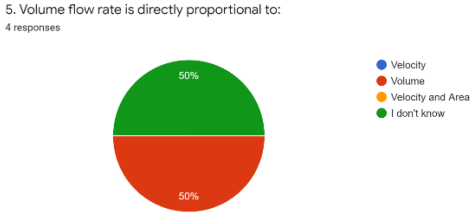


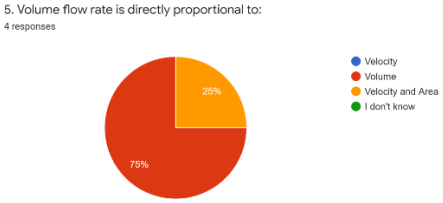






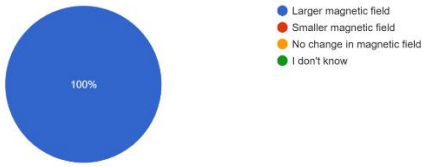






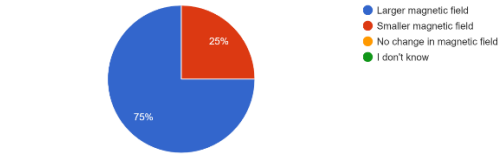
6. Larger Current means:

4 responses



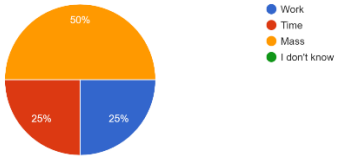
6. Larger Current means:

4 responses



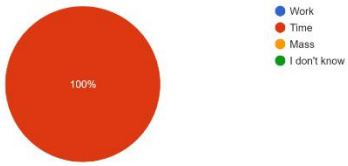
7. Power depends on Energy and:

4 responses



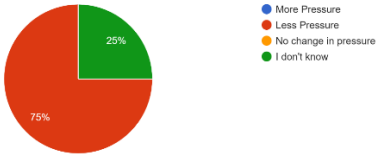
7. Power depends on Energy and:

4 responses



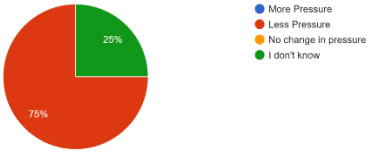
8. Larger Area means:

4 responses



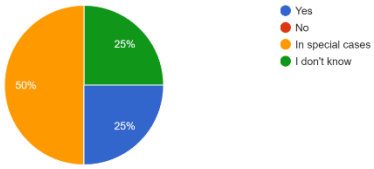
8. Larger Area means:

4 responses



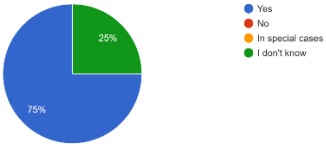
9. Does the speed of sound depend on temperature?

4 responses



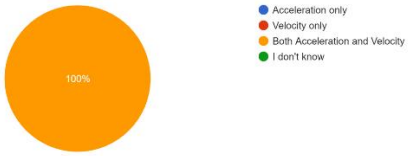
9. Does the speed of sound depend on temperature?

4 responses



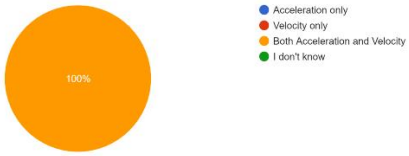
10. Projectile motion depends on:

4 responses



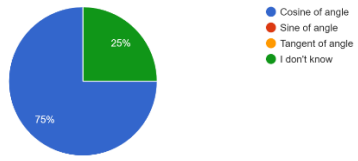
10. Projectile motion depends on:

4 responses



11. Dot product gives magnitudes multiplied by:

4 responses

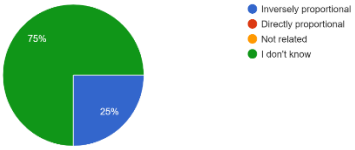


11. Dot product gives magnitudes multiplied by:

4 responses

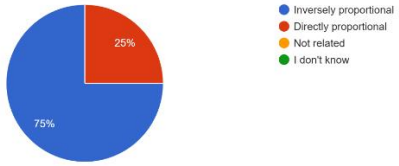
12. Linear Frequency and time period are:

4 responses



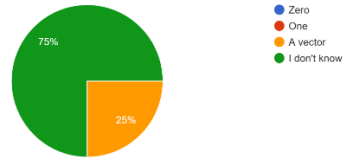
12. Frequency and time period are:

4 responses



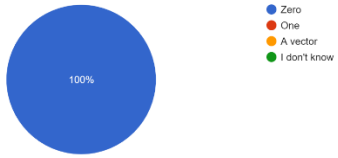
13. Divergence of a curl always gives a:

4 responses



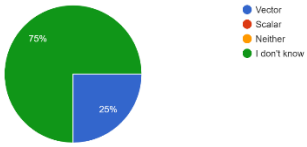
13. Divergence of a curl always gives a:

4 responses



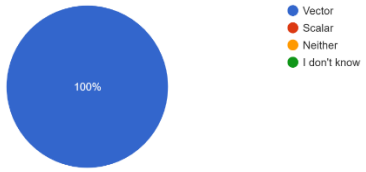
14. Del is a:

4 responses



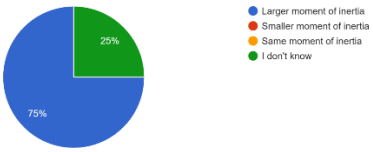
14. Del is a:

4 responses



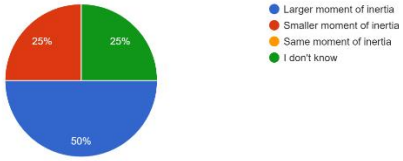
15. Larger mass means:

4 responses



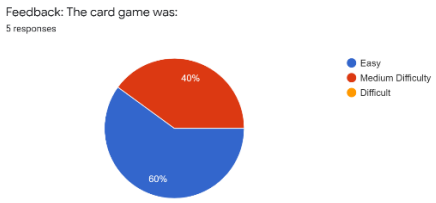
15. Larger mass means:

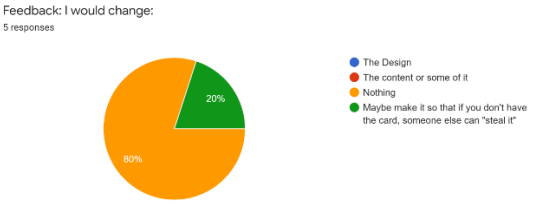
4 responses

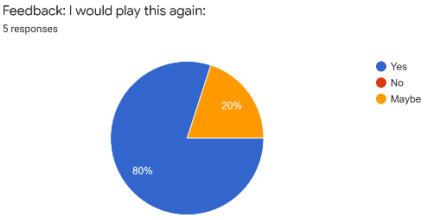


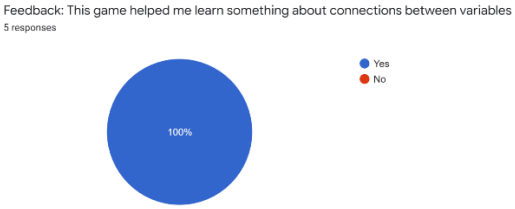
Appendix B: Feedback from Seniors and Juniors

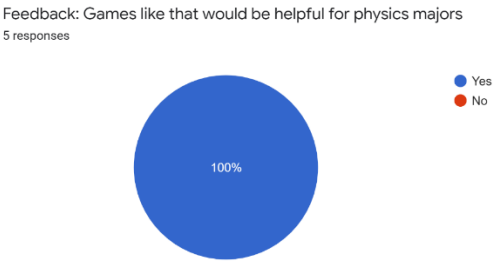
Senior feedback



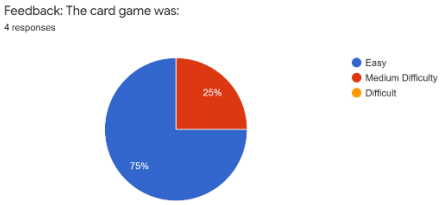


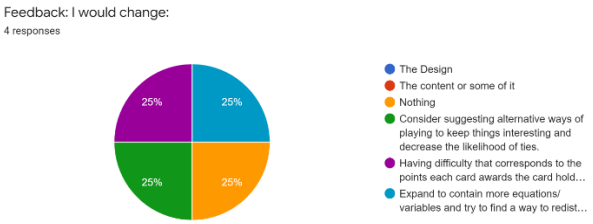


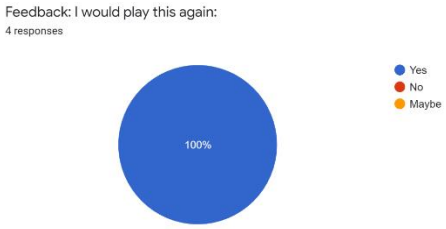


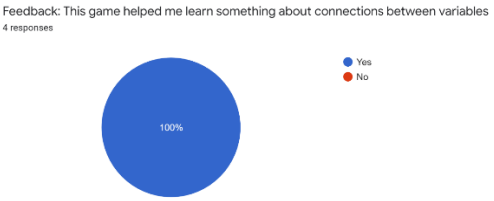


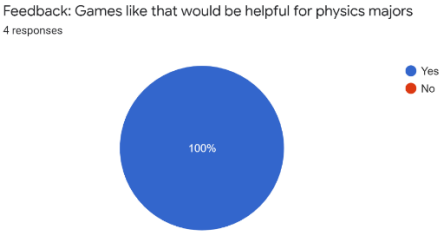
Junior feedback



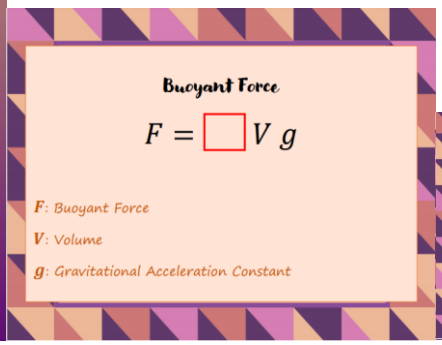


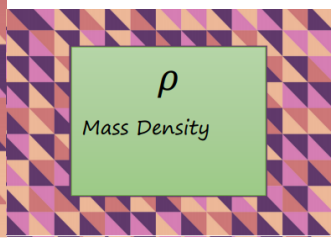






Appendix C: Game sample pictures (picture sizes are relative to the real sizes)






Capacitors in Series
$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$
C_s: Capacitors in Series
C_2: Second Capacitor
C_3: Third Capacitor
R: Gas Constant
m: Molecular Mass
unit vector
unit vector
unit vector
wire


FYSIXO