Gamification Of Physics Education: Using Extrinsic Gaming Motivators to Improve Learning Outcomes in a First Year Undergraduate Course

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Introduction

Purpose

• To rigorously test the benefits of game-based learning in education

• To attempt to improve student motivation

• To attempt to improve student enjoyment of their course material
• Two types of Quizzes, list-style (traditional) and gamified-style

<table>
<thead>
<tr>
<th>List Style</th>
<th>Gamified Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>All questions available simultaneous</td>
<td>Questions are given one question at a time</td>
</tr>
<tr>
<td>A correct response gives a student a mark</td>
<td>A correct response gives a student points</td>
</tr>
<tr>
<td>The value of a question is fixed</td>
<td>The points received for a correct response depends on streaks</td>
</tr>
<tr>
<td>Final grade presented as [ \frac{\text{Number of correct responses}}{\text{Total Number of questions}} ]</td>
<td>Final grade presented as Total score</td>
</tr>
<tr>
<td>A passing mark is 60%</td>
<td>A passing mark is set to be of equivalent difficulty to 60%</td>
</tr>
</tbody>
</table>
Design

The Gamified Quiz

\[ K \times \frac{c-1+n}{c} \times N \]

<table>
<thead>
<tr>
<th>Quiz Number</th>
<th>Number of Questions</th>
<th>c</th>
<th>K</th>
<th>Points To Pass</th>
<th>Points Needed for One Star</th>
<th>Points Needed for Two Stars</th>
<th>Points Needed for Three Stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiz 1</td>
<td>19</td>
<td>10</td>
<td>20</td>
<td>1656</td>
<td>2382</td>
<td>4402</td>
<td>8360</td>
</tr>
<tr>
<td>Quiz 2</td>
<td>6</td>
<td>2</td>
<td>150</td>
<td>1650</td>
<td>2100</td>
<td>4200</td>
<td>8400</td>
</tr>
<tr>
<td>Quiz 3</td>
<td>15</td>
<td>5</td>
<td>25</td>
<td>1245</td>
<td>2075</td>
<td>3705</td>
<td>8600</td>
</tr>
<tr>
<td>Quiz 4</td>
<td>11</td>
<td>8</td>
<td>55</td>
<td>1683</td>
<td>2310</td>
<td>4675</td>
<td>8470</td>
</tr>
</tbody>
</table>

\( n \) number of correct responses answered consecutively

\( N \) number of correct responses total so far

\( c \) Determines the weight of the streaks

\( K \) Normalizes the points
Design

The Gamified Quiz

- Additional Gamified Elements

- Students can earn up to three stars, depending on the number of points received

- Instant feedback given after each response

- Leaderboards and badges were implement in the second term
Welcome to the Gamification of Physics Education (GOPE) Gaming Platform

Thank you for volunteering to be a part of our efforts to develop new innovative and engaging physics education methods for our students. In particular, these pretests begin an effort to utilize elements of gaming in undergraduate physics.

While the content and the concepts assessed remain the same as for our traditional pretests, these pretests function differently than those you may be used to. Here is a brief overview of what to expect:

- You will be awarded points for a correct answer, rather than just a “yes/no” mark.
- The more questions you answer correctly, the more points each subsequent question is worth.
- The more questions you answer correctly consecutively i.e. in a row, the more points each subsequent question is worth.
- As is the case with the traditional pretests, you must score a minimum number of points to pass the quiz.
- Stars are not a requirement to gain access to the quiz room and will have no effect on your grade. However, they are meant as a source of motivation for students.
- When you have successfully completed your pretest you will receive a receipt which you must print and bring to the quiz room as proof.
- Hover your mouse over the various components in the quiz for an explanation as to what they mean.

Please send any feedback or issues to jrose07@uoguelph.ca
Two transparent fluids are in contact at a plane interface. A ray of light is incident on the interface. Which drawing below is correct if \( n_1 > n_2 \)?

A

B

C
One of the statements below is incorrect, which one?

The myopic eye has a too short distance from the cornea to retina.

The distance from the cornea to the retina is too large for the total power of the refracting surface in the eye.

The astigmatic eye has a cornea with a different curvature in different directions.

Good!
One of the statements below is incorrect; which one?

- The myopic eye has a total power of its refracting surfaces too large for the distance from cornea to retina.
- The distance from the cornea to the retina in the hypermetropic eye is too large for the total power of the refracting surface in the eye.
- The astigmatic eye has a cornea with a different curvature in different directions.
One of the statements below is incorrect. Which one?

Snell’s law is: \( n \sin \theta_i = n' \sin \theta_r \)

The angle of reflection = The angle of incidence

\( n = c/v \), where \( n \) is the index of refraction in the medium, and \( c \) is the speed of light in a vacuum.

The angle of reflection = The angle of incidence

Incorrect

Lock In Answer
The power of this surface is:

\[ n_1 = 1.5 \quad \text{and} \quad n_2 = 2.0 \]

1/4 m

Brilliant!
**Question 1:** The drawings show the intensity profile of the diffraction patterns of two small sources of light, after the light has passed through a small circular aperture.

In which case are the two images just on the verge of being resolved?

- C
- B
- A

**Question 2:** Given below are several formulas relating energy \( E \), frequency \( f \), angular frequency \( \omega \), wave vector \( k \) along with Planck's constant \( h \) and the speed of light \( c \) for an EM wave (or photon). One of them is incorrect; which one?

- \( E = \frac{hck}{2\pi} \)
- \( E = \frac{hc}{\lambda} \)
- \( c = \frac{f}{\lambda} \)
- \( E = hf \)
- \( E = \hbar\omega/2\pi \)

**Question 3:** Below are 4 graphs as a function of distance \( x \). Which one represents the probability density \( P \) as a function of position along a \( \pi \)-bonded linear molecule of length \( l \) for an electron in the \( n = 2 \) state.
Method

Course Website
Already Established
Old Graphics
List-Style Quizzes
Control Group

List-Style Quizzes
Developed for This Study
New, Updated Graphics
List-Style Quizzes
Control Group

Gamified Quizzes
Developed for This Study
New, Updated Graphics
Gamified Quizzes
Test Group
Method

- Students required to write pre-tests

- Pre-tests given to students not worth grades

- Students are required to pass a minimum threshold in order to get into the quiz room

- No difference to students final grade once student minimum threshold

- List style quizzes, threshold at 60%. For gamified, points adjusted for similar difficulty
Method

• Once a student achieves the minimum threshold, very little course-based extrinsic motivators remain

• The number of attempts after the passing attempt was measured motivation

• The percentage of students in each group who made attempts after passing until they achieved perfect was measured

• Finally, all students completed a survey at the end of the term
Results

Average Number Of Attempts After Passing
(P = .124, .045, .024, .015)

Gamified
List-Style
Results

Percentage of Students Who Attempted Pre-Test After Passing Until a Perfect Score (N = 125, P = .027, .144, .001, .004)
Results

Percentage of Students Who Made Attemps After Getting Perfect (N = 125)

- Pre-test 1
- Pre-test 2
- Pre-test 3
- Pre-test 4

Gamified
List-Style
Survey Results (N= 361)

I liked the format of the pre-tests ($P= .000, .000$)

<table>
<thead>
<tr>
<th>Format</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>List-Style</td>
<td>50%</td>
</tr>
<tr>
<td>Gamified</td>
<td>80%</td>
</tr>
<tr>
<td>Courselink</td>
<td>40%</td>
</tr>
</tbody>
</table>

Series1
Survey Results (N= 361)

I found working through the pre-test to be an enjoyable exercise (P = .001, .000)
I found the pre-tests to be engaging (P = .000, .000)
Survey Results (N= 361)

I found that the pre-tests helped prepare me for the quizzes (P = .881, .281)
I would like to see elements of gaming used as a teaching tool in more of my classes (Gamers vs Non Gamers) (Gamers, P = .346, .499, Non gamers P = .000, .000)
Conclusions

• Higher levels of motivation are observed for students taking Gamified Pre-tests
• A large fraction of students are motivated by the extrinsic reward of stars
• Overall, students find the Gamified pre-tests more engaging, enjoyable, and they like the format better
• Students who have experience with gaming or gamification want more gamification
• Students who do not consider themselves gamers do not see the need for more gamification, until they experience it
Further Research

• Would higher levels of difficulty maintain high levels of motivation?

• Can we exaggerate these results with other techniques (e.g. avatars, fantasy gaming elements, stories, etc)

• How much does class exposure effect results?

• Remove students ability to take other groups quizzes
Acknowledgements

- Boom Digital Media group developed The GOPE website and gaming platform