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Incorporating Gamification at an Engineering Statistics course to improve student learning and engagement

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Incorporating Gamification at an Engineering Statistics course to improve student learning and engagement

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Abstract

The ability to apply standard statistical measures is very useful in the engineering profession as it is concerned with developing and studying methods for collecting, analyzing, interpreting, and presenting data. Importantly, statistics is a highly interdisciplinary field that provides methodologies to gather, review, analyze and draw conclusions from data. While statistical methods are very useful, many engineering students struggle with basics concepts and fail to see the applicability. In an effort to develop a deeper understanding and appreciation for basic statistical methods, we incorporated a number of games that require students to apply methods in a fun and engaging environment. Gamified learning includes using game attributes to affect learning-related behaviors in a positive manner. To enhance student learning and engagement, a series of game-based elements such as dice games, peer competition, and Kahoot quizzes were incorporated into the curriculum of a probability and statistics course for civil and construction engineering at The Citadel. Probability and statistics is a crucial knowledge area for future practice engineers, and therefore, very important to increase student comprehension on the topic. The impact of the use of gamified material was examined via student surveys and instructor assessment of student engagement and enthusiasm for the subject among multiple student sections.

Keywords

Gamification, Gamified learning, Probabilities, Statistics, Engineering

Introduction

Engineering courses for sophomore and junior students usually require the students to start thinking on applying mathematics in real and more tangible contexts, and develop their problem-solving skills. Engineers must be prepared to collect, handle and analyze data and turn it into a useful form to assist in decision making and to make educated decisions involving risk. For engineering students taking a first course in probability and statistics, it is important to develop a basic understanding of how to assess event outcomes and their corresponding probabilities to make intelligent, informed decisions [1].

An understanding of probability distributions is required to better understand the effects of randomness, variation and averages of sampling distributions. Teaching these concepts is challenging, however, there is a growing body of literature supporting the use of “gamification” as a fun, innovative, and effective way of teaching key statistical concepts. Gamification has been described as the integration of game design in non-game contents into the curriculum in order to improve students' motivation, academic achievement, and attitudes toward lessons. [2]

A key objective of engineering education is to integrally develop concepts, aptitudes, and abilities with the motivation to learn in order to prepare future engineer to tackle problems and develop solutions to the challenges that society faces. Gamification is one strategy that can be employed to increase engagement and motivation in engineering education. Gamification provides the means to integrate the mathematical concepts with a high practical component to generate interest and engagement by the students, as well as ways for students to build critical thinking skills, social skills, and professional competencies. [3]. Gamification provides an opportunity to teach students and promote learning within a fun, engaging and enjoyable environment. A vital element of games is the immediate feedback which confirms the player's action and presents results of that action. The ultimate goal of employing games is to be a tool that contributes to enhancing the students' learning.

Gamification in a Statistics course

Course Description

The CIVL 331 - Probability and Statistics for Civil and Construction is a required course, taught at the civil, environmental, and construction engineering department by engineering professors, developed to introduce students to the concepts and techniques necessary to organize and analyze data. Descriptive statistical measures and probability theory are combined to provide the basis for statistical decision-making and data analysis techniques applicable to the practice of civil and construction engineering. Topics include data collection and presentation, measures of central tendency; measures of variability; basic probability laws and distributions; sampling theory, confidence intervals, hypothesis testing, analysis of variance, regression analysis, process control, and forecasting. The focus is on problem solving and on decision-making that can be applied to the practice of civil, and construction engineering. The course learning outcomes include:

1. Analysis: Access, manipulate and analyze data using excel. Produce appropriate graphs and descriptive statistics for one and two variables, for both categorical and continuous data, and calculate measures of dispersion and variation. Use random variables and associated analytical functions to quantify the likelihood of various outcomes from experiments, monitoring efforts, and observation

2. Comprehension: Distinguish between population and sample data, and categorical and numerical data. Distinguish between random and non- random sampling and create such samples. Interpret graphs and descriptive statistics for one and two variables. Know and apply the basic probability rules, the concepts of expected value and variance for discrete and continuous variables. Know and apply the Central Limit Theorem, which is crucial for inference.

3. Synthesis: Understand confidence intervals and hypothesis tests. Carry out and interpret one-sample and two-sample analysis for means and proportions. Carry out and interpret statistical modeling using regression and analysis of variance. Know and apply basic quality control procedures. Develop and interpret forecasting models. Evaluate the likelihood of different outcomes in a variety of real-life applications.

Games Incorporated

In CIVL 331, games are used as an active learning technique during class to help students connect the probability concepts learned in lecture to the course learning objectives and concept reinforcement. On a broad level, the goal is to demonstrate probability is at work in diverse settings and to encourage students to discover ways to apply probability to aid in decision making. Following in-class lectures and example problems, students complete reading assignments and homework problems outside of class which involve computing probabilities. This frees up in-class time to introduce the games and run through several game rounds over multiple classes.

The introduced games included Skunk, and Can't Stop along with the Kahoots web-based learning platform where student mastery of learning concepts is tested using Kahoots quizzes. These quizzes provide instant feedback for every student in the class and also track learning progress over time for formative assessments.

The incorporation of gamification has two main goals: i) help students identify and review the main concepts and theories being taught, and ii) encourage application of learned skills to problem solving. By introducing elements of games, we expected students to be more willing to engage in the courses and obtain the maximum profit of in-class time (while improving their grades).

The game Can't Stop is used to introduce students to the applications of random probabilities and expected value. The goal of the game is to climb to the top of a rope column before any of the other players can. But the more the player risks rolling the dice during a turn, the greater the probability of losing the advances made during that turn.

Can't Stop Game Rules [4]

Players try to win three of the eleven number columns as quickly as possible. To do this, they

- choose 3 circular markers of a chosen color
- Roll 4 dice, Pair them 2 by 2 and add the results. For example, see below where the numbers in the red box represent the sum of two pairs of dice.

Figure 1. Pair Dice Summation Combinations Example in Can't Stop

- Pick one combination and advance on the respective ropes (Figure 2). If none of your markers can advance, you have to stop and lose all the progresses of this round.

- A marker can only advance on one rope if it is already in it or unassigned, and the rope has not already been claimed

- Decide if keeping rolling or stopping, to "save" your new positions on the ropes.

A vital element of games is the immediate feedback, visual and/or auditive. This feedback confirms the player's action and presents to him/her the results of that action [5]. The Can't Stop game was chosen due to its fast pace and visual scorecard which communicates immediately the status of the current activity to the students as they climb the rope. When a player climbs all the way to the top of a rope, he claims that rope. Any other player's marker on that rope gets eliminated. The first person to claim 3 ropes wins the game!

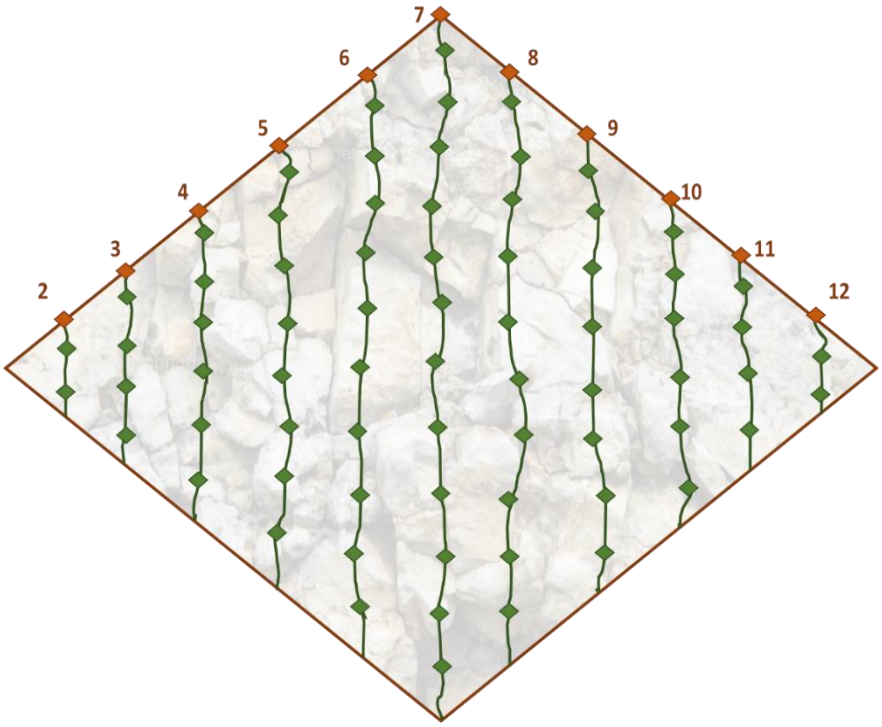

Figure 2. Can't Stop Number Ropes Playing Diagram

During their turn, players may roll the dice as long as they wish -provided they can place or move at least one of the runners. If, after rolling the dice, a player is unable to move, his turn ends immediately and s/he loses everything that was achieved during that turn. The object of the game is to be the first to claim 3 ropes.

We have found that Can't Stop is effective in teaching students the concepts of expected value and how it can be applied to estimate the return you can expect for some kind of action, like selecting two pairs of dice from a roll of 4 dice in order to select columns to occupy. It is also useful in teaching the concept of combinations as we ask students to compute possible outcomes of rolling the four dice. The calculations also provide an opportunity to help students understand and practice reporting of significant digits. For example, we ask students to calculate how many times we can roll 4 dice and get one of the 6 results on each. An example of the calculations is shown below.

- Possible rolls disregarding repetitions? **6*6*6*6 = 1296**
- How many ways can we roll 4 dice?

  I. Four Singles (ABCD)

  II. One Pair (AABC)

  III. Two Pairs (AABB)

  IV. Three of a Kind (AAAB)

  V. Four of a Kind (AAAA)

- Four Singles (ABCD): 6/6 * 5/6 * 4/6 * 3/6 = 27.70%
  One Pair (AABC): 6/6 * 1/6 * 5/6 * 4/6 * 4C2 = 55.50%
  Two Pairs (AABB): 6/6 * 1/6 * 5/6 * 1/6 * 4C2/2 = 6.94%
  Three of a Kind (AAAB): 6/6 * 1/6 * 1/6 * 5/6 * 4C1 = 9.25%
- Four of a Kind (AAAA): 6/6 * 1/6 * 1/6 * 1/6 = 0.46%

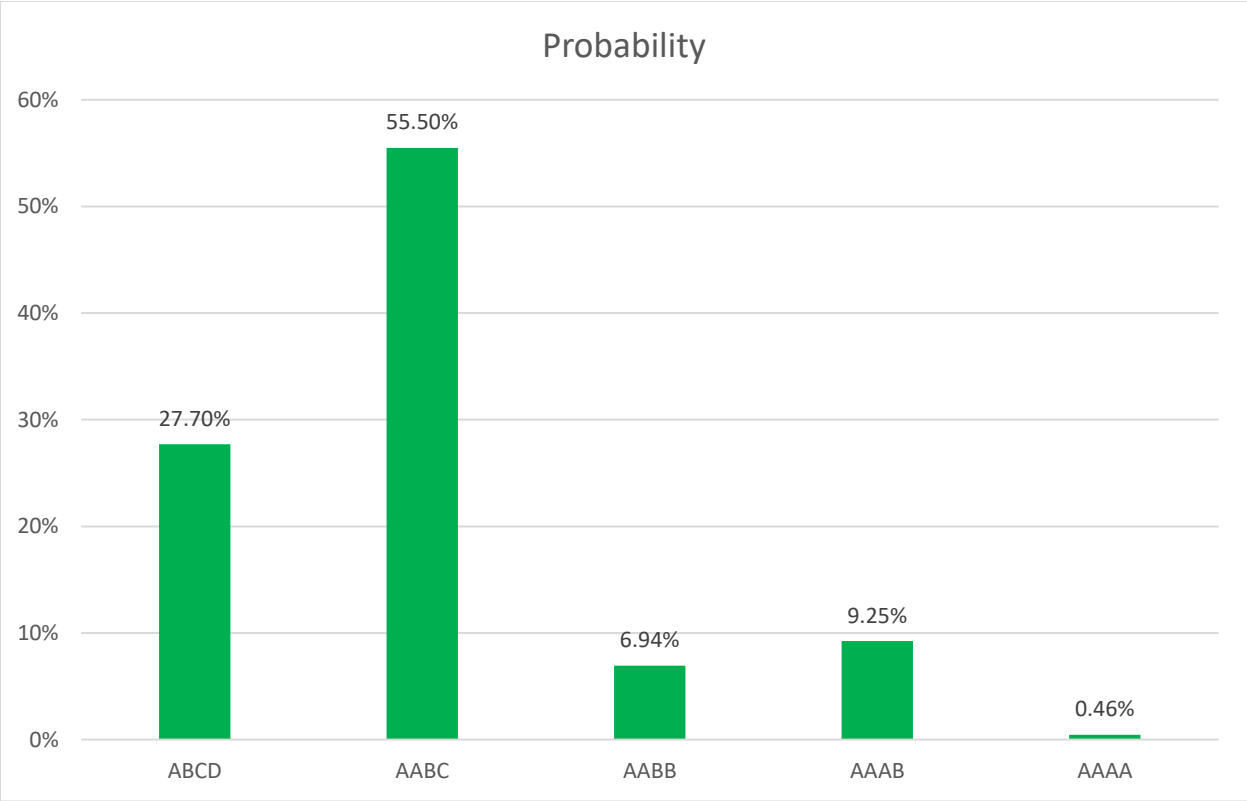

Figure 3. Probability Distribution For Different Roll Combinations

- Probability of rolling each number.

- 2 1/36 2.78%
- 3 1/18 5.56%
- 4 1/12 8.33%
- 5 1/9 11.11%
- 6 5/36 13.89%
- 7 1/6 16.67%
- 8 5/36 13.89%
- 9 1/9 11.11%
- 10 1/12 8.33%
- 11 1/18 5.56%
- 12 1/36 2.78%

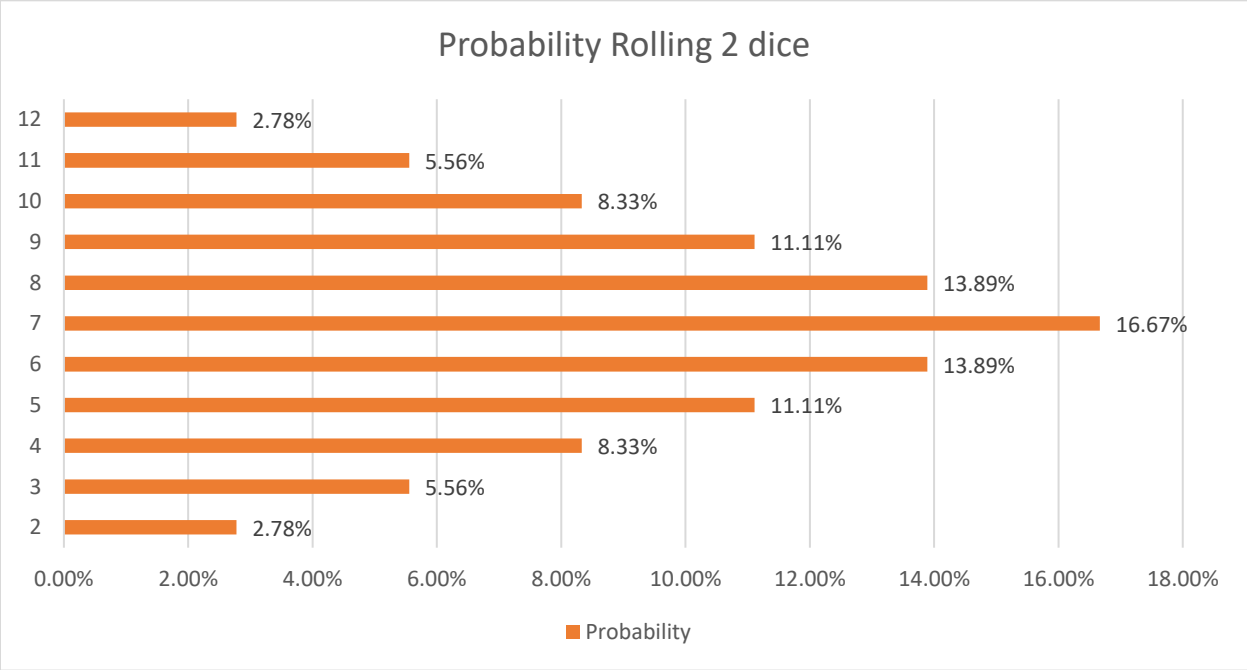

Figure 4. Probabilities Associated with Rolling 2 Dice

- Combining the two previous tables with some additional consideration, we obtain the probability to obtain each number with each roll of 4 dice.

Table 1. Probabilities of Rolling 4 Dice

2	13.19%
3	23.30%
4	35.57%
5	44.75%
6	56.10%
7	64.35%
8	56.10%
9	44.75%
10	35.57%
11	23.30%
12	13.19%

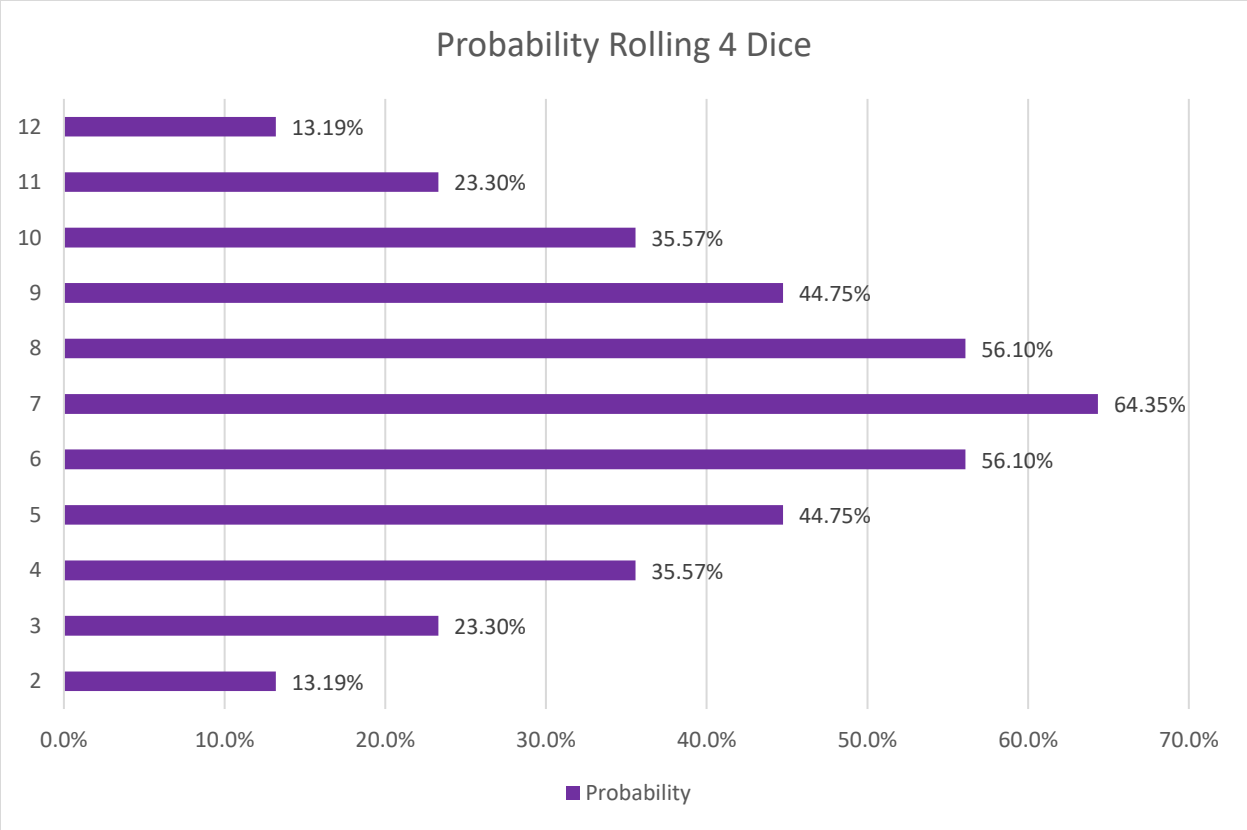

Figure 5. Probabilities of Rolling 4 Dice

The game Skunk is used to introduce students to how probabilities can affect decision making using the following Game Rules [6]

Each letter of "skunk" represents a different round of the game; play begins with the "S" column and continues through the "K" column. The object of "skunk" is to accumulate the greatest possible point total over the five rounds. The rules for play are the same for each of the five rounds. To accumulate points in a given round, a pair of dice is rolled. A player gets the total of the dice and records it in his or her column, unless a "one" comes up. If a "one" comes up, play is over for that round and all the player's points in that column are wiped out. If "double ones" come up, all points accumulated in prior columns are wiped out as well. If a "one" doesn't occur, the player may choose either to try for more points on the next roll or to stop and keep what he or she has accumulated. Note: If a "one" or "double ones" occur on the very first roll of a round, then that round is over and the player must take the consequences. When students are first introduced to the game, they make the decision to keep playing or stop randomly. However, after a few games, students are introduced to how probabilities can influence our decision making by calculating when the chances of getting some more points out-weighs the risk of losing all with the following:

- If the total score for the round is *t,* then if you roll at least a 1 you lose *t.* If you don't roll a 1 you gain an average of 8. (Try averaging all the combinations that have no 1s and will get 8, or just think that the possible outcomes are 2, 3, 4, 5, 6, averaging 4 each dice => 8 for the sum)

- What are the probabilities of not rolling 1s? $(\frac{5}{6})*\left(\frac{5}{6}\right) = (\frac{25}{36})$.

- Therefore, the probabilities of rolling 1s is $\frac{11}{36}$

- The total chances for the roll to be a positive one are the probabilities of rolling a specific outcome multiplied by the average gain (or loss)

$$(\frac{11}{36})*(-t) + (\frac{25}{36})*8 > 0 \quad => \quad 11*t<200 \quad => \quad t<18.2$$

Therefore, when the sum of the round is reaching 18, it is safer to stop.

Students' Perspectives

About two weeks before the semester ends, students taking the Statistics course were asked about how they viewed the introduction of games into the class, if those games helped them comprehend the material better and what other games they would like to see implemented in the class. Some of the student answers are listed below:

1) "My favorite part of the class has been Kahoot! and Skunk. There were fun and interactive."

2) "Favorite part about class so far are the [K]ahoot games, they helped me better understand the theory."

3) "I have loved all the games and Kahoots we have played. I would like to see any gambling/ card game to show the probability and statistical aspect to how poker/gambling works."

4) "I enjoyed Skunk very much. I would like to see some Heads Up Seven Up".

5) "I really liked the games in class. Putting the statistics to use helps me learn the material better".

6) "I really enjoyed [S]kunk and [K]ahoots. I would pick to have more dice games in class".

7) "I enjoyed the skunk game, it gave me a good understanding of probabilities and how we can use them in our every-day lives."

8) "Kahoot is fun as it shakes up the monotony of lectures. Especially when turned in to a competition, I tend to forget that i'm working on what i would consider to be uninteresting problems and focus on beating my classmates."

Based on the survey results, 100% of the students enjoyed the reinforcement of probability and statistics theory using games. Also, 71.3% of the students, would like to see more games in the future.

Instructor's Perspectives

CIVL 331had been taught several times prior to the introduction of "Gamification". Based on student feedback and the anecdotal observations, the instructors overwhelmingly agreed that the level of student interest, engagement and enthusiasm in the classes has markedly increased.

Conclusions and Future Research

The gamification activities presented in this paper allow students to get hands-on experience evaluating events of random chance in an interesting context. In addition, the activity helps reinforce the idea that both event outcomes and their corresponding probabilities should be assessed when making decisions involving risk. While students often baulk at the dreary context of flipping a coin or drawing black and white balls from urns, our students remained engaged throughout the activities discussed in this paper. In general, the authors' concluded that gamification has a positive effect in engineering education by making difficult subjects more manageable, increase intrinsic motivation, scientific knowledge, collaboration, interest and reduce or better manage work load. The authors' plan to continue incorporating gamifications and conducting further research to more fully explore the experience of the participants. It is hoped that continued use of gamification will gain momentum that will yield many research results in the near future, especially in the field of engineering education at all levels.

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