Incorporating Mastermind to Help Undergraduate Neurobiology Students Improve Their Ability to Build Scientific Arguments

In order to develop into effective researchers, educators, and science professionals, students must internalize the basic principles of reasoning and scientific design. These skills can improve with training [1], but they can be difficult to teach as concepts within the classroom. The English code-breaking game known as Bulls and Cows, was popularized as the game Mastermind, and has been adapted for a variety of applications in the fields of mathematics, computing and psychology [2-4]. This game has been proposed as a tool for teaching logic in mathematics courses [5], but the problem-solving skills emphasized in the game could also be relevant to the sciences both within the classroom and in the laboratory setting [6-8]. Yet, little work has been done to determine if the Mastermind game is effective at helping students develop these necessary skills.

In this pilot study, the Mastermind game was incorporated during non-required breakout sessions for undergraduate neurobiology students. Approximately 20-30 students were given a set of data relating to the course material and asked to develop scientific hypotheses, propose experiments necessary to test them and to draw conclusions from this information. Due to the limited number of students, no control group was established. These responses were assessed following a designed 20 point rubric that remained constant throughout this work. Following the prompt, students formed small groups and were asked to break the color code of an online version of Mastermind. Briefly, Mastermind is a code-breaking game in which the codebreaker tries to guess the pattern, in both order and color, of a series of colored pegs within twelve turns. Each guess is made by placing a row of six colored pegs on the decoding board. Once placed, the codemaker provides feedback by placing zero to four key pegs in the small holes of the row with the guess. A black key peg is placed for each color code peg from the guess that is correct in both color and position. A white key peg indicates the existence of a correct color code peg placed in the wrong position. Students were asked to record how many "experiments" it took to break this code. This training was repeated a total of three times throughout the semester to determine if the students’ abilities to build scientific arguments would improve after playing Mastermind.

From these experimental tasks, it was determined that students’ abilities to answer the given prompts dramatically increased throughout the three trial sessions. The mean prompt scores increased from 7.5 to 15.11 out of 20 points over the course of the semester. When this work began, students’ responses were inexperienced and feeble and their ability to draw concrete conclusions from the given data was underdeveloped. Specifically, the mean score obtained from drawing conclusions in the prompts increased from 1.85 to 6.32 out of the possible 8 points. Yet, when the number of trials it took for students to break the Mastermind code in the online game was observed, it was found that there were no significant improvements from the beginning of the semester to the end.
Our findings seem to support the previously held belief that the Mastermind game can be effective in helping students develop critical thinking skills. Yet, because the Mastermind performance did not dramatically improve during this study, we cannot concretely say that the improvement on prompt scores was a direct outcome of the Mastermind game play. I recommend that this work be repeated with a larger group of students to observe if the Mastermind scores show improvement over the course of a semester. If improvement is seen, this would suggest that our findings were an artifact of the small sample size. If no improvement is again observed, this would support the idea that student improvements were not directly correlated with playing the Mastermind game. Yet, the Mastermind game could still serve as an important teaching tool. Not only does it incorporate non-traditional teaching approaches, but many students were more willing to participate with the game and prompts, when compared to the traditional lecture styles. Also, based on Strom and Barolo’s [7-8] discussion about the Mastermind game, five teachable moments can occur during gameplay. Utilizing the Mastermind game seems to help students develop i) well-controlled experiments that allow for specific conclusions to be made, ii) over-interpretation of data can lead to false conclusions, iii) negative data can be valuable, iv) good experimental design can save time and v) test a hypothesis as severely as possible, but if it is invalid, discard it immediately [7]. These teaching points are the basis of all scientific research and if students are able to thoroughly learn them, they will be able to apply these critical thinking skills in future learning and laboratory settings.