The Impact of 5E Instruction while Teaching Molecular Genetics in General Biology

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ABSTRACT

The purpose of this research was to determine the effect of the 5E model on the understanding of the molecular genetics concepts taught in general biology. The research had a quantitative focus and a quasi-experimental design, and the participants were 40 undergraduate students from a private university in the west of Puerto Rico, which were divided in two control groups and one experimental group. The initial data was obtained through a pretest that measured the understanding of molecular genetics concepts. The treatment lasted six weeks and consisted of the instruction of the topics of DNA structure and replication, transcription, translation, and mutations. The after-instruction understanding of the concepts was evaluated through a posttest. The results showed that the 5E model had a significant effect (p < 0.05) in generating a higher understanding of the concepts presented.

Key Words: science education; biology; active learning; inquiry-based learning; 5E instructional model.

Introduction

Science education is defined as “the organized instruction through which our society attempts to direct youth in its understanding of the material universe” (Barnes, 1961, p. 394). This is an issue of crucial importance in the 21st century, given that humans live in a time in which topics such as climate change, new infectious diseases, and genetically modified organisms make necessary that the general population has basic scientific knowledge to understand things that affect their daily lives (Workosky, 2017). Occasionally, media disseminates incorrect opinions that spread rapidly due to the lack of basic scientific knowledge (LeVine, 2016).

Also, science education seeks to foster in young people the interest in choosing professional careers in STEM and dedication to discovering things together in the classroom (Seymour & Hewitt, 1997, p. 148).

Justification

It is essential to use instructional methods that generate in science students active and relevant learning and that explain simply the complex vital processes, linking the macroscopic and microscopic or molecular scales (Lin & Hu, 2003; Ragsdale & Pedretti, 2004; Songer & Mintzes, 1994). This learning must be an active process that emphasizes a purposeful interaction between the students and their learning environment and the use of knowledge in a way that is meaningful to their daily lives (Correiro et al, 2008, p. 457).

From the constructivist perspective, learning should be a process in which each individual creates their own knowledge, based on their life experiences and life views (Correiro et al., 2008, p. 457). The active learning techniques include role play, animations, simulations, molecular models, flipped classroom, among many others. These techniques help understand abstract and tridimensional concepts, such as subcellular processes (Voltzow, 2016). Beyond using these techniques individually, there is the possibility of integrating them in different stages of a learning cycle.

Learning cycles have been long proposed in science education, since these provide the student the opportunity to learn by challenging their initial conceptions through self-reflection and interaction with other students (Bybee, 1997, as cited in Duran & Duran, 2004, p. 51). The learning cycle used in this research was the 5E, which is a constructivist, active-learning, and inquiry-based method that consists of five stages: engagement, exploration, elaboration, explanation, and evaluation. It should be noted that there is a large and constantly growing amount of educational research that proves the efficacy of college-level biology inquiry-based instruction (Caccavo, 2011, p. 521).
Research Questions

The research questions were the following:

- How do the groups under study compare at the beginning of the research regarding understanding of molecular genetics concepts?
- What is the difference in understanding of the groups under study, after the instruction of the molecular genetics concepts using the 5E model?
- What effect will the 5E instructional model have over the understanding of students in molecular genetics concepts?

Research Design

The research conducted has a quantitative focus and a quasi-experimental design. This means that the groups were class sections that already existed in the institution. The students were not randomly assigned to the groups. The researcher assigns the groups as experimental and control, administers pretests to both, conducts experimental activities only with the experimental group, and then administers a posttest to evaluate the differences between both groups.

Population

The population consisted of undergraduate students in the bachelor degree programs of a private university in the Northwestern Puerto Rico region who were enrolled in the General Biology II course. The students were selected from a single institution, since variations in the syllabi between higher education institutions and the differences in the student body characteristics could have represented additional variables.

Sample

The research took place during the spring 2019 semester. Three preexisting course sections were selected, from which two (Experimental Group and Control Group One) were taught by the researcher and one (Control Group Two) was taught by another faculty member with similar teaching experience. The assignment of these groups as Experimental, Control One, and Control Two was randomized, using Microsoft Excel. The total of students that participated in this research was 40. From these 40 students, 14 were part of the Experimental Group, 14 composed Control Group One and 12 belonged to Control Group Two.

Research Instrument

The instrument used in the research was a content test of 21 multiple choice items, which was created by the researcher. The instrument was validated by a group of five experts with doctoral degrees in biology and education who were university professors from several institutions. A pilot study was conducted with a group of students who did not participate in the research, to determine the reliability of the instrument. The Kuder-Richardson test showed that the reliability of it was high (0.783).

Treatment

The treatment had a duration of six class periods of three hours (six weeks). Both control groups received the unit information through lecture and PowerPoint. The experimental group received the information through the 5E learning cycle. The five stages of the cycle were conducted three times, as can be seen in Table 1. All three groups received the instrument as a pretest and posttest, before and after the pedagogic intervention, respectively.

Descriptive Analysis of the Data

Findings of the Pretest Scores

To conduct the analysis of the data obtained through the administration of the research instrument, descriptive statistics were used. The knowledge test was administered to each group under study before the beginning of the unit. Table 2 presents the average scores obtained by the three groups in the pretest.

In Table 2 it was observed that Control Group One obtained the highest average score in the pretest results when compared to groups Control Two and Experimental, which seems to suggest that Control Group One had a slightly higher understanding of the molecular genetics concepts at the beginning of the research.

Table 1. Activities of the 5E instructional model conducted with the experimental group for each topic.

| Stage     | DNA Structure & Replication                      | Transcription & Translation          | Mutations                                           |
|-----------|--------------------------------------------------|--------------------------------------|-----------------------------------------------------|
| Engagement| Questions; initial discussion                     | Questions; initial discussion         | Questions; initial discussion                       |
| Exploration| DNA paper models; DNA candy models               | Storyboards                          | “Mutated monsters” game                            |
| Explanation| Animations                                       | Animations; role play; gene expression puzzle | Animations; gene expression puzzle (effect of mutations) |
| Elaboration| Think, pair, share; group discussions; new situations | Think, pair, share; group discussions; new situations | Think, pair share; group discussions; new situations |
| Evaluation| Kahoot quiz                                      | Kahoot quiz                          | Kahoot quiz                                        |
Table 2. Average scores of the pretest of all groups under study.

| Group       | N | Average | Standard Deviation |
|-------------|---|---------|-------------------|
| Control 1   | 14| 6.64    | 3.342             |
| Control 2   | 12| 6.42    | 2.151             |
| Experimental| 14| 6.43    | 2.065             |

Control Group Two had the lowest score in the pretest results. In the next subsection, whether these differences are significant will be discussed.

**Findings of the Posttest Scores**

When the treatment was concluded, each group under study was administered the posttest. Table 3 presents the averages and the standard deviations obtained by each group, after the instruction of the unit.

After finalizing the treatment, the Experimental Group obtained a higher score in the averages of the results of the posttest when compared to groups Control One and Control Two, which seems to suggest that the Experimental Group obtained a higher level of understanding of concepts than the other groups. The group under study that obtained the lowest score in the results of the posttest was Control One. In the next subsection, whether these differences are significant will be determined.

**Statistical Tests for Research Question 1**

To compare the understanding of molecular genetics concepts between the groups at the beginning of the research, the pretest results were submitted to the analysis of the normal distribution of the data, using the Kolmogorov-Smirnov normality test. All groups presented a normal distribution. In order to determine the homogeneity of the variances, the result of the Levene test was analyzed. It demonstrated that the variances were homogeneous. After proving that the data of the pretest were normally distributed and that the variances were homogeneous, a one-way ANOVA test was performed to determine if the differences between the groups at the end of the research were significant. Table 4 presents the results of this test.

To determine in which groups there was significant difference, the results were submitted to the multiple comparison test Post Hoc Tukey. The results of this test showed that between Control Group One and Control Group Two, the value was $p = 0.110 > 0.050$. However, when the results between Control Group One and the Experimental Group were analyzed, the value was $p = 0.002 < 0.050$. Also, the results between Control Group Two and the Experimental Group were analyzed. The results showed a value of $p = 0.295 > 0.050$.

**Statistical Tests for Research Question 2**

What is the difference in understanding of the groups under study, after the instruction of the molecular genetics concepts using the 5E model? In order to compare the understanding of the concepts of molecular genetics between the groups, after the treatment, the results of the posttest were submitted to the analysis of the normal distribution of the data through the normality test Kolmogorov-Smirnov, revealing that again all groups possessed a normal distribution. In order to determine the homogeneity of the variance, the result of the statistical test Levene was analyzed to determine if the variances were homogeneous. After proving that the data of the posttest were normally distributed and that the variances were homogeneous, a one-way ANOVA test was performed to determine if the differences between the groups at the end of the research were significant. Table 5 shows the results of this test.

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**Table 3.** Average scores of the posttest of all groups under study.

| Group       | N | Average | Standard Deviation |
|-------------|---|---------|-------------------|
| Control 1   | 14| 10.07   | 3.689             |
| Control 2   | 12| 12.92   | 3.777             |
| Experimental| 14| 15.00   | 3.013             |

**Table 4.** Results of the one-way ANOVA test for the groups at the beginning of the research in the understanding of molecular genetics concepts.

|                  | Sum of Squares | gl | Quadratic Means | F   | Sig.  |
|------------------|----------------|----|-----------------|-----|-------|
| Between groups   | 0.440          | 2  | 0.220           | 0.032| 0.968 |
| Within groups    | 251.560        | 37 | 6.799           |     |       |
| Total            | 252.000        | 39 |                 |     |       |

**Table 5.** Results of the one-way ANOVA test for the groups at the end of the research in the understanding of molecular genetics concepts.

|                  | Sum of Squares | gl | Quadratic Means | F   | Sig.  |
|------------------|----------------|----|-----------------|-----|-------|
| Between groups   | 171.255        | 2  | 85.627          | 7.012| 0.003 |
| Within groups    | 451.845        | 37 | 12.212          |     |       |
| Total            | 623.100        | 39 |                 |     |       |
the nonparametric test Wilcoxon was performed. Table 6 presents the findings of said test.

For this analysis, the data of the pretest and posttest of the experimental group were considered. The results of this test showed a value of $p = 0.001 < 0.050$. In addition, the results of the ranges test showed that 93% of the participants had an improvement in their scores.

### Inferential Analysis of the Data

#### Research Question 1

How do the groups under study compare at the beginning of the research regarding understanding of molecular genetics concepts? After analyzing the pretest results, data suggests that there was no significant difference between the groups at the beginning of it in the understanding of molecular genetics concepts. In other words, in that moment, all groups were homogeneous in their understanding, so none of the groups had an advantage over the others at the beginning of the research.

#### Research Question 2

What is the difference in understanding of the groups under study, after the instruction of the molecular genetics concepts using the 5E model? The analysis performed using the posttest data showed there was no significant difference between Control Group One and Control Group Two, both of which received traditional instruction, meaning their understanding after the instruction was homogeneous. On the other hand, there was significant difference between Control Group One and the Experimental Group, which means that the understanding in the Experimental Group was significantly superior to that of Control Group One after instruction. Finally, the analysis showed that there was no significant difference between Control Group Two and the Experimental Group, meaning that although the Experimental Group had higher posttest scores than both control groups, the post instruction understanding of this group was not significantly superior to that of both control groups, just one of them (Control Group One).

#### Research Question 3

What effect will the 5E instructional model have over the understanding of students in molecular genetics concepts? The analysis of the pretest and posttest data of the Experimental Group showed that there was significant difference between the results at the beginning and at the end of the instruction using the 5E model, which means that the treatment developed in this research possibly had a significant effect in improving their understanding. Also, 93% of the participants had an improvement in their scores, which evidenced the effect of the treatment over the performance of the participants.

### Conclusion

This research examined the understanding of undergraduate students in molecular genetics concepts at a general biology level. In addition, it compared two instructional methods: the 5E learning cycle and the traditional instruction based on lecture with PowerPoint. Based on the results presented in this paper, the following conclusions were established:

- With respect to the understanding of molecular genetics concepts at the beginning of the research in the groups under study, it is concluded that the groups were homogeneous and that, therefore, the observed differences at the end of the research cannot be attributed to discrepancies in the previous understanding.
- In terms of the understanding of molecular genetics concepts of the participants of this research, it is concluded that the instructional model of the 5E learning cycle constituted an appropriate and effective teaching method to improve learning. The students instructed through the 5E model had superior performance in molecular genetics concepts to the students instructed through traditional methods. Notwithstanding, since the difference was not statistically significant with respect to one of the control groups, it can be concluded that both methods were effective in similar manners.
- Lastly, in terms of the effect of the 5E instructional model over the understanding of molecular genetics concepts, it can be concluded that it has a significant positive effect, being related to an improvement in test scores.

### Recommendations

Based on the findings of this research, there is an evident need for the use of pedagogical strategies that foster active and participative learning in students. From the data and its corresponding interpretation, the following is recommended:

- Incorporate the molecular genetics instructional unit developed as part of this research in the general biology course, in the following academic terms.
- Develop more instructional units based on the learning cycle for different science courses, especially the ones that include molecular concepts.
- Train the science faculty in the use of strategies and instructional models of active learning, such as the 5E learning cycle.
- Promote that educational institutions obtain modern equipment and materials that facilitate the creation and development of activities.
- Conduct similar research projects to determine the effect of the 5E model on the learning of other courses in biology, chemistry, microbiology, and physics.
- Conduct similar research projects that include a qualitative component to observe and document the interactions between the students and the instructor during the treatment and the opinions of the students about their experience.
• Replicate this research in other public and private universities inside and outside Puerto Rico, to compare the results obtained with the ones of this research.
• Have control and experimental sections for both instructors, so that the difference between instructional methods can be studied without interference of other human variables.

○ Limitations
In this part, the limitations of this research are presented.
• The period of instruction of the topics that were part of the research was six weeks. In future research projects, the whole semester can be included in the treatment.
• The number of topics that were part of the research was limited to molecular concepts. In future research projects, other topics of the course can be included.
• The number of students that composed the sample was small. In future research projects, a larger sample can be selected.
• In addition, there was a possibility that in the participants occurred the Hawthorne effect, in which individuals experience changes in their behavior as a result of knowing that they are objects of study (McCarney et al., 2007).

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