# A Biology Class with Online Game Foldit to Improve Junior High Students' Performance

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**Abstract:** In this study, a biology class with online game *Foldit* is developed to improve junior high students' performance during and after the class. To evaluate the effectiveness and influence of this class, thirty-three students in different junior high schools participate in the experimental class, those students are divided into two grades to have the class individually, Grade 8 and Grade 9. Learning achievement, learning interest, learning attitude and students' responses are four dimensions to examine students' performance. According the experimental results, students from two grades have significant higher percent correct after the experimental class, but students' learning achievements in Grade 8 have stronger connection with the class, that is, the gamified class with *Foldit* has more influence on students of Grade 8 in learning achievement. After analyzing students' questionnaires, students in both grades show higher interest in this biology class with online game *Foldit*, which means gamified class can activate students' interest and improve their attitude in biology class in junior high schools. Besides, students' responses also show that using small groups to play the game in class can stimulate students' collaborations in groups and competition with other groups.

## 1. Introduction

Biology is an important part of the science study, yet compared to other courses in junior high school, biology course is relatively overlooked in curriculum schedule. Meanwhile, there are full of abstract terms and contents in junior high school biology subject that requires students with logical and flexible thinking. Teachers' teaching strategy is unitary and scattered knowledge, so most students feel bored and lose their interest in biology [1, 2].

Science educators are urged to develop active-learning strategies that helps students comprehend the abstract concepts their application in real world [3]. It is essential for teachers to adopt methods that can improve students' overall quality and ability, especially motivate their active learning [4], such as setting questions, multimedia applications and student-oriented discussion [1, 5].

Therefore, applying gamification in education is also becoming a rising trend to deal with school problems [6]. Gamification is the use of game elements in non-game contexts to promote people's engagement [7]. It has already been adopted into many domains like marketing, politics, health and fitness, and Student engagement is the first thing to consider when teachers prepare their class, based on the function of gamification, applying game elements in class could motivate students and improve their engagement even when studying tedious tasks [8] and at the same time, gamified context provide students opportunities to cultivate resilience in the face of failure [7]. However, Gamification also has its disadvantages, for example, students are more active when they play the game, but teachers don't prepare to maintain class in order, so chaos would happen in class. Besides, some teachers use rewards to improve students' engagement, this method seems effective. However, it also has shortcomings, students would only learn when they can be rewarded and cannot form automatic learning [9]. The ultimate goal of gamification is to increase intrinsic motivation and drive students' learning behaviors.

*Foldit* is an online protein folding game which people try to solve the one of the hardest problem in biology. *Foldit* is friendly to naive Players. They can use manipulation tools to predict the protein structure based on their spatial reasoning ability [10]. Protein structure has a strong connection with its function, which means if protein wants to perform normal function, it should have right spatial structure other than right sequence [11]. The problem of the right protein sequence has been solved in the online game *Foldit*, and what players need to do is to predict the three-dimensional structure of protein

The purpose of this study is to first point out the difficulties of teaching in junior high school biology course. By introducing the online game *Foldit*, this study tries to improve the in-class performance. Specifically, it focuses on the biologic knowledge of protein synthesis and the connection between protein structures and functions, and *Foldit* is adopted to offer students a direct view about the spatial structure of protein. With the manipulation of the game, students are expected to deepen the understanding of the molecule biology instead of being imparted abstract terms and tedious explanation from teachers.

## 2. Methods

To evaluate the effectiveness of the innovative approach with *Foldit* implemented, an experiment was conducted on junior high school students biology class to evaluate the learning outcomes and attitude of the students. The selected subject unit was "Gene controls the traits of living things." This unit aims to foster students' ability to master the connection between gene and traits of living things. Teachers usually add the function of protein in this unit as additional knowledge to help students better understand how genes control the traits.

### 2.1. Participants

The participants for this study were 33 junior high students from different local schools on a voluntary basis. They were students studying in the same extracurricular cram school. These thirty-three students included fifteen students from Grade 8 and eighteen students from Grade 9. Although this study involved students from two grades, these students have all learned the basic knowledge of molecular biology, such as gene, DNA and protein under the same educational system in Sichuan, China, so they had no knowledge gap when in the experimental class. However, students from different grades were taught in two classes which the content and difficulty were same. In order to motivate students' engagement and avoid unnecessary chaos, students in each class were divided into small groups and teacher scored each group's performance when they were in the game *Foldit* time.

### 2.2. Procedure

All the students in this experiment are required to study the unit Gene controls the traits of living things as mandated in biology syllabus. Students in this experiment formed self-control, Grade 8 and Grade 9 were experimented individually in consideration of students from different grade had different cognitive and thinking ability. This process is divided into three parts: pre-experiment, experiment and post-experiment. Before the experimental class, students took the pre-test to evaluate their basic knowledge about molecular biology in the unit "Gene controls the traits of living things." Following that, students learned this unit knowledge again with the online game *Foldit*. Students firstly learned the definition and function of gene, and then learned the traits of living things. When they learned how gene controls the traits through protein, *Foldit* was implemented to assist the teaching.

Before starting the game, students in each class were divided into three group, that is, Grade 8 had five students in each group and Grade 9 had six students in each group. As mentioned before in Klopfer E (2009), gamified class has obvious shortcomings like disorder in class, so dividing students into small groups assist teachers to manage the classroom. Besides, students in small groups could also have collaborations through their discussions and thinking sharing, which not only enable

students to show respect but also facilitate their performance in class [12, 13]. Teachers used scores to reward groups performing well in the game session, in this condition, students in each group had a competition with others so that their groups could have higher scores.

Teacher explained the rules and showed how to play the game *Foldit*, students needed to drag the mouse and rotate the protein in order to get the protein in a right structure avoiding clashes, the system of *Foldit* can automatically record score, the higher the score is, the more correct the protein's structure is, that is, students can also use the score above the interface to determine the structure is correct. Considering the allocation of class time, students played three game rounds and each group chose three students to play the game, one game round had three students from different groups, teacher only scored the group that had highest score in the *Foldit. Fig.1.&2.*

After the learning activity, students took the post-test and post-questionnaire for measuring their achievements and their thoughts about this innovative teaching approach.
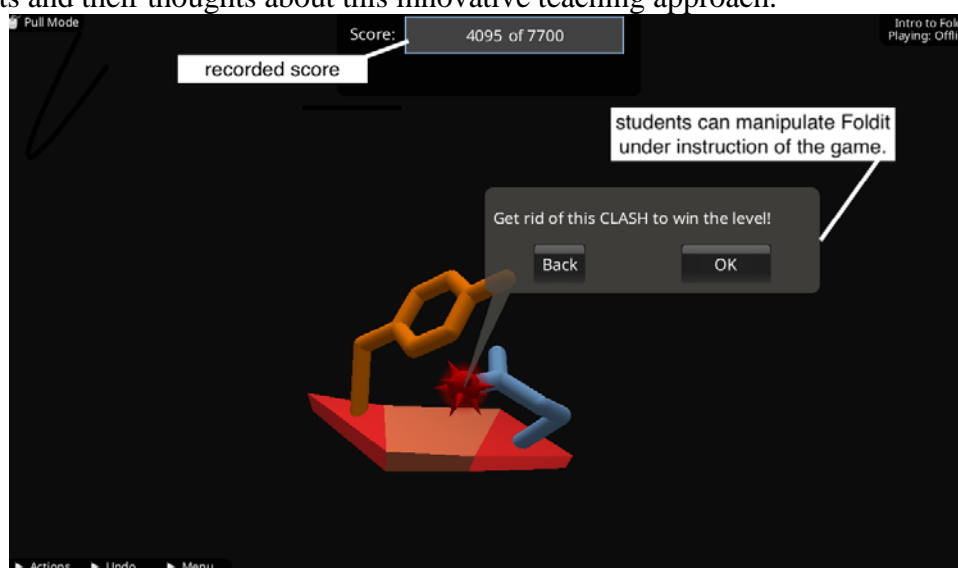
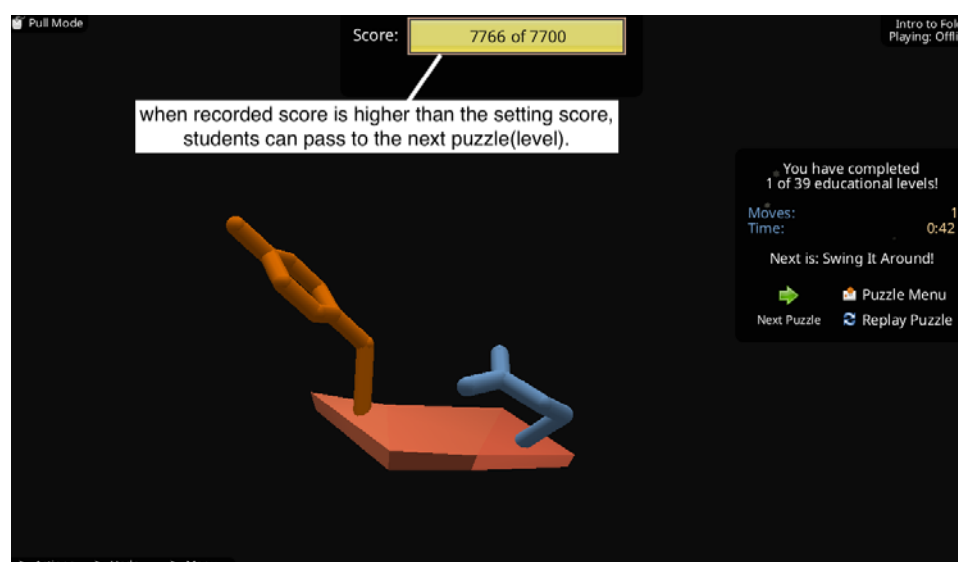Figure 1. The interface of *Foldit* (starting the game)

Figure 2. The interface of *Foldit* (passing the game)

## 2.3. Measurements

Two standardized tests and one questionnaire are delivered to the participants throughout the experiment. In pre-experiment stage, a standardized test is delivered to students. After the experiment, another standardized test is conducted again. It then supplement with questionnaire used

for measuring the learning interest and learning attitude of the students regarding the innovative biology class.

Both pre-test and post-test were chose through past unified examinations and practice examinations. The pre-test aimed to ensure all the students in the same class had an equivalent basic knowledge of the biology course content. It consisted five short answers with a perfect score of 25 for evaluating students' knowledge. The post-test aimed to identify any change in students' score or achievements after the experiment, it consisted ten multiple-choice items with a perfect score of 20.

The questionnaire for measuring the learning interest and learning attitude was modified from Hwang and Chang (2011) [14]. The learning interests consisted 11 items on a five point scale, where "5" represented "strongly agree" and "1" represented "strongly disagree".

## 3. Results

### 3.1. Learning achievements

Before the experimental class, all students took a pre-test to ensure students had equal abilities and basic knowledge in biology subject. According to table l, the mean and standard deviation of pre-test were 15.00 and 4.629 for Grade 8, and 15.56 and 5.659 for Grade 9. The t-test result showed these two groups of students did not have significant difference (t=-0.304, p>0.05), that means students of Grade 8 and Grade 9 had equal abilities and basic knowledge in biology before learning the unit "Gene controls the traits of living things".

After participating in the experimental class, students from Grade 8 and Grade 9 took the post-test. And because the perfect scores of the pre-test and post-test are different, the percent correct of each student was used to complete the t-test. As shown in Table 2. The mean of post--test percent correct was 77.33 for Students from Grade 8, 17.33 higher than pre-test, and the standard deviation of post-test (10.328) was lower than pre-test (18.516). In addition, the relation of these two tests was -0.75 and the p value (0.008) was less than 0.05, that is, students from Grade 8 took two tests and the two tests had definite negative relation, students had better percent correct and stable abilities to deal with the difficulties in this biology unit after being exposed to the class with online game *Foldit*.

Students from Grade 9 also had better post-test percent correct (from 62.22 to 79.44) and they even had better post-test standard deviation (from 22.637 to 9.984), but the relation of this two tests was only -0.098 (p<0.01) That is to say, the post-test percent correct did not have strong connection with the pre-test percent correct for Grade 9, the experimental class with *Foldit* had less effect on students from Grade 9. However, the number of students of Grade 9 was small is another reason to explain the weak relation of these two tests.

### 3.2. Learning interest and learning attitude

Table *3* shows the t-test results of the questionnaire scores of the students in two Grades. It is found that students from Grade 9 had a higher learning interest than students from Grade 8 (t=-2.219, p<0.05), as for the learning attitude, Grade 8 was 3.381, and Grade 9 was 3.246, so Grade 8 had statistically higher learning attitude than Grade 9 (t=2.107, p<0.05).

### 3.3. Students' responses

According to the experimental methods, students from each grade were divided into three groups and teacher used scores to activate students. During the experimental class, students were more excited when teacher told they would play a online game, and after hearing the illustration of the game, students in each group had strong desire to play the game. And because teacher used scores to rank each group, most students behaved positively and wanted to have a try, which means students in each group formed certain competition. Besides, although each round game only allowed one student from one group, other students in each group participated in discussions in order to get higher scores for their own group, and students shared their ideas and opinions among discussions, so they had some collaboration as teacher wanted. Students' positive responses also explained their questionnaire

results, most of them thought this class with online game *Foldit* was interesting and filled high scores in question 8, 9, 10 and 11 of "Learning interest" part of questionnaire. *Fig. 3*.

## 4. Discussion and conclusions

The aim of this study is to combine existing online game *Foldit* with traditional Chinese biology class and explore the effect of gamified class. As mentioned previously, Chinese students in junior high school often think biology is a difficult subject as students learn biology firstly in junior high school and biology has many abstract terms confusing students. Meanwhile, traditional Chinese teaching methods are unitary which make students feel more bored and have less interests in biology class [1, 2]. Gamification in education has been researched for many years and it has the trend to deal with school teaching problems [6], so the relevant biologic online game *Foldit* is used in this experiment to activate students' interest and improve their attitude and achievements in biology class.

In this study, thirty-three students from Grade 8 and Grade 9 participated in this experimental class. And according to their age, they were divided into two groups to have the biology class to study the unit "Gene controls the traits of living things".

Table.1. The t-test of pre-test results

| Grade | N | Mean | Standard Deviation | t | F value | p |
|-------|----|-------|--------------------|--------|---------|-------|
| 8 | 15 | 15.00 | 4.629 | -0.304 | 1.117 | 0.763 |
| 9 | 18 | 15.56 | 5.659 | | | |

Table.2. The t-test of pre-test and post-test percent correct results

| Grade | N | Mean | | Standard Deviation | | Relation | t | p |
|-------|----|----------|-----------|----------|-----------|----------|--------|-------|
| | | Pre-test | Post-test | Pre-test | Post-test | | | |
| 8 | 15 | 60.00 | 77.33 | 18.516 | 10.328 | -0.75 | -3.070 | 0.008 |
| 9 | 18 | 62.22 | 79.44 | 22.637 | 9.984 | -0.098 | -2.892 | 0.011 |

Table.3. The t-test of questionnaire of two Grades

| Dimension | Grade | N | Mean | Standard Deviation | t | p |
|-----------|-------|----|-------|--------------------|--------|-------|
| Learning interest | 8 | 15 | 3.158 | 0.180 | | |
| | 9 | 18 | 3.308 | 0.205 | -2.219 | 0.034 |
| Learning attitude | 8 | 15 | 3.381 | 0.159 | 2.107 | |
| | 9 | 18 | 3.246 | 0.201 | | 0.043 |

All students took the pre-test to ensure that they have equal abilities in biology subject, and the t-test result showed that students from two grades had no significant difference in basic knowledge. After the pre-test, students from two grades had the game assisted class, both classes had three groups, Grade 8 had five students in each group and Grade 9 had six students in each group. When students had the *Foldit* game, they had group competitions to get higher scores and group collaboration during discussions to solve the problems in *Foldit* game. The post-test showed that students from both grades had higher percent correct than the pre-test and students from both grades had more stable percent correct in the post-test. However, the relevant of pre-test and post-test was stronger in Grade 8, that is, the experimental class had more effect on the Grade 8. Thirty-three students also took the questionnaire for learning interest and learning attitude after the whole class. Students in Grade 8 had higher learning attitude but lower learning interest than students in Grade 9, and both students in Grade 8 and Grade 9 had higher mean value in the last four questions of "Learning interest" part.

This experimental class only had thirty-three participating students, and they were divided into two classed according their grades, so the total amount of each class got smaller, this factor may have influence on the data analysis. Besides, Chinese students in Sichuan province pass their unified examination of biology in Grade 8 and students do not learn any knowledge about biology after the

examination, so students in Grade 8 may have clear memory about the knowledge than students in Grade 9, which means this factor also has some effect on the test scores of the students from different grades.

In the future study, more students and control-experiment groups will be considered to get the better data. Moreover, in this experiment, students only take the questionnaire after the class, so the analysis builds on the difference between two grades. In the next step, the pre-questionnaire and post-questionnaire will be used to complete the contrastive analysis of individual students in Learning interest part and Learning attitude part.

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# Appendix 1 Questionnaire

*Learning interests*

1. Ordinary biology is interesting.
2. Learning more about biology is interesting.
3. I always look forward to taking biology course and prepare for it before class.
4. The teacher's instructions in this biology course have attracted my attention.
5. Anything concerning biology is always interesting to me.
6. Biology course is more interesting to me in comparison with other courses.
7. Other courses do not attract me as much as biology course.
8. Innovative biology class (such as multimedia, game, and discussion) is interesting.
9. This online game implemented class is interesting.
10. Learning with peers in this biology course is interesting.
11. It is interesting to answer those questions while learning in the field during the special biology course.

*Learning attitudes*

1. Biology course is valuable and worth studying.
2. It is worth learning those things about biology
3. It is worth learning biology course well.
4. It is important to learn more about biology, including learning in class and experimenting in daily life.
5. It is important to know biologic knowledge and put it into practice.
6. 6. I will actively search for more information and learn about biology.
7. 7. It is important for everyone to take biology course.

# Appendix 2: Pre-test

*Pre-test (each question deserved 5 scores)*

1. What chemical elements does DNA have? And what chemical elements do proteins have?
2. Draw the basic molecular structure of proteins?
3. Explain the relationship among chromosomes, genes, DNA and proteins?
4. Explain how genes control the traits of living things?
5. Explain what elements determine the function of proteins?

# Appendix 3: Post-test

*(each question deserved 2 scores)*

1. Compare the relationships among Chromosome, Gene and DNA, the correct is (    )
A. Chromosome > DNA > Gene
B. Gene > DNA > Chromosome
C. Chromosome > Gene > DNA
D. DNA > Gene > Chromosome
2. The correct relationship between Chromosome and Gene is (    )
A. Many genes are arranged on chromosomes
B. Many chromosomes are arranged on genes
C. Gene is another name of chromosome
D. When chromosomes are in cell nucleus called genes
3. The basic units of protein are (    )
A. L-α-amino acid
B. D-α-amino acid
C. L-β-amino acid
D. D-β-amino acid
4. In addition to the eight essential amino acids, the essential amino acids specially needed by infants are (    )
A. Tryptophan

B. Leucine

C. Histidine

D. Tyrosine

5. Protein plays an important role in life activities. It has (　　)

A. Regulatory action (hormonal proteins that regulate metabolic responses, such as insulin and growth hormone, etc.)

B. Transport function (such as hemoglobin carrier)

C. Motor function (such as actin, myosin, microactin, etc.)

D. Immune protection(interferon)

6. Proteins contains (　　)

A. Carbon

B. Nitrogen

C. Sulfur

D. Oxygen

7. The following statement about amino acids is correct (　　)

A. The α-carbon atoms in all amino acids except glycine are asymmetric carbon atoms.

B. Amino acids are optically active.

C. Each amino acid has two stereoisomers, D and L.

D. The amino acids in the known natural proteins are all L-type.

8. Secondary structure types of proteins are (　　)

A. Spiral structure

B. β-folding strand

C. β-folding sheet

D. Folding

9. Factors affecting the tertiary structure of proteins include (　　)

A. Hydrogen bond

B. Disulfide bond

C. Van-der Waals force

D. Electrostatic interaction

10. All proteins have (　　) structure.

A. First

B. Second

C. Tertiary

D. Quaternary