INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 12, Issue 3, (2023) E-ISSN: 2226-6348

Fundamental of Dna Structure Illustration in Genetic Teaching and Learning

[1]Tengku Norbaya Tengku Azhar, [1]Norhafizah Mohd Zazi, [1]Malissa Mohamed, [1,2]Norlizayati Ramlan, [1]Muhamad Rahimi Che Hassan, [1]Noorakmal Abd Wahab, Siti [1]Noorfahana Mohd Idris, [1]Puteri Noor Safura Megat Mahmud, [3]Nur Azalina Suzianti Feisal

[1]Centre Foundation Studies, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil, 43800, Selangor, Malaysia, [2]Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia, [3]Department of Diagnostic and Allied Health Science, Faculty of Health and Life Sciences, Management and Science University, Shah Alam 40150, Selangor, Malaysia.

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v12-i3/17877 DOI:10.6007/IJARPED/v12-i3/17877

Published Online: 13 September 2023

Abstract

Advance genetic syllabus at pre university level involving DNA replication, protein synthesis and gene technology. The purpose of this study is to identify the level of understanding on DNA structure using illustration of DNA drawing and its correlation with the learning performance in advance genetic. (N=101, 71 females, 30 males) of pre-university students from science stream successfully recruited for the study. Students has been tested to draw the DNA structure and underwent a simple test on replication, protein synthesis and genetic technology. This study reported that over the six criteria of structure; bases; deoxyribose; phosphate; primary structure; secondary structure and organizational level, the lowest mean scored was the criteria of linkage symbol between the bases (BA3) with $\bar{x}$= 0.16±0.42 while the highest mean scored was a base pair symbol (BA1) with $\bar{x}$= 1.06±1.48. This study also discovered that the drawing criteria; (Hydrogen bond symbol between bases (BA2), deoxyribose symbol (DE) and DNA organization (OR) were significantly correlated to protein synthesis test score with (r=-0.209, P=0.036; r=0.203, P=0.042; r=-0.37, P=0.001) respectively. Besides that, the criteria such as DE, DNA primary structure- a linkage between deoxyribose and phosphate (PR2) and OR also significantly correlated to the genetic technology test score with (r=-0.035, P=0.001; r=0.559, P=0.001; r=0.248, P=0.012). The whole criteria scores, also significantly correlated to the protein synthesis test score with (r=0.238, P=0.017) but not for gene technology test score. It thus summarizes that the understanding on DNA structure is crucial for conceptualization of process in genetic study like replication and protein synthesis.

Keywords: DNA Structure, Illustration, Replication, Protein Synthesis

Introduction

Background of Study

A common problem faced by the biology students is a proper understanding of the three genetics concepts which are DNA, gene, and chromosome (Langheinrich *et al.,* 2015). DNA (deoxyribonucleic acid) is a large molecule containing the genes that code for instructions of the synthesis of proteins. The code consists of a sequence of repeating subunits called nucleotides. Each nucleotide consists of three major components: a phosphate group, a sugar (deoxyribose), and nitrogenous bases.

Genetic literacy involves basic knowledge of the genome that carries a variety of meanings as well as understanding how to obtain a variety of information using only a small portion of the entire genome. Knowledge on DNA structure is paramount to discover another advanced genetic concept like replication, protein synthesis and genetic technology. Protein synthesis is sufficiently a complex process which responsible for protein synthetic machinery in all organisms.

Statement of Problem

At higher education level, problem on teaching and learning of this topic arisen due to the diversification in teaching and learning. Every student has their own unique learning nature at different level of difficulty and personalities. With diverse learning wavelengths, abilities, and misconception, the understanding towards fundamental concept such as basic DNA structure is important to determine student performance and understanding in related advanced topic. In many cases, students faced a problem such as lack of engagement and motivation in learning in genetic due to difficulty of the topic as well as poor understanding on the fundamental concept (Cimer, 2012; Özcan, 2003). In addition, students especially from life science background commonly struggle to visualize and interpret between the static two-dimensional (2D) images displayed in textbooks (Jittivadhna et. al., 2010). As the consequences, many students have a misconception about structure–function relationships after the lesson ends (DeSutter et. al., 2017).

Objective of the Study and Research Questions

This study is done to highlight the issues on the important of fundamental basic structure of DNA towards advance genetic topic. Three research questions had been addressed in this study which are;

- How illustration of genetic structure from can be used to measure students' understanding on DNA structure?
- What is the level of student's understanding on DNA structure based on drawing as tools?
- How do the comprehension of DNA structure correlates to students' performance for related topic like DNA replication, protein synthesis process and gene technology?

Literature Review

Genetic, the toughest science syllabus

Introduced as one of the core syllabus components in many educational levels in Malaysia, starting from secondary school until university level, students must well understand these concepts to apply in various fields. Recently, the understanding of genetic knowledge has become increasingly important in life, especially in relation to health (Dudlicek, 2004). Application of these concept ranging from molecular basis of genetic diseases through

antibiotic development until the expressing recombinant proteins as drugs becomes as an important concept to the learners.

Challenge in teaching and learning genetic

In every teaching and learning session, the educator aim is to ensure all the knowledge is well delivered while the learners perceive, process, store, and recall what they are attempting to learn most efficiently and effectively. However, ironically, there are no specific teaching and learning styles that relevant to science education especially in biology education. According to Avena et al (2019) genetic topic specifically to genes and chromosome is considered as a difficult concept in biology and always affects students' motivation and achievement. From the perspective of lecturers, difficulty in delivering the content vanquish student engagement with the topic (Cimer, 2012). Worse come to worst, student with several misconceptions might lose focus and interest to the topic. The old-style on teaching and learning genetics using method such as lecturing "straight from the book "or memorizing concept from notes is a way behind the attractive learning approach.

Methodology

This study is a qualitative study that addressed students understanding on DNA structure using diagram illustration as previously done in the study by Langheinrich and Bogner (2015). Ethical approval has been received from Research Ethics Committee of Universiti Teknologi Mara(UiTM) with reference of REC/02/2023(ST/MR/37). N=101 respondents among pre-university students from institution in Selangor area had been chosen in the study. Sample size was calculated according to one mean of sample size. Test-retest was applied to 20 students as the pilot study (r =0.946, $p<0.001$, n=20) on the first week of program. In the second to fourth week of the program student has been exposed to the genetic topic. Within that period, student has been tested through online platform to draw the DNA structure. 71 females and 30 males were responded to the test which done through google classroom platform. Students was accessed using six criteria of DNA structure; bases (BA1, BA2, BA3); deoxyribose (DE); phosphate (PH); primary structure (PR1, PR2); secondary structure (SE) and organizational level (OR) as presented in Appendix I. For this assessment, student was strictly prohibited to copy or refer to any source of information while drawing the DNA in given time. They also not trained by the instructor during the time of acquisition. In the sixth week of the program, students underwent a simple test on replication, protein synthesis and genetic technology with a structured test question. All the instructor that involved in the study was trained to mark the diagram. Every instructor must submit the marked DNA diagram to second examiner to ensure the consistency of marking. The same method applied for replication, protein synthesis and genetic technology with a structured test question.

Statistical Analysis

All of the score from the DNA diagram and the respective test were performed using the SPSS Statistical Software (Version 20) for windows. The student's answer was analyses using descriptive analysis in term of numbers, percentage, mean score and standard deviation. The association between the DNA structures knowledge with DNA replication, protein synthesis and gene technology test score were analyse using Pearson correlation. The significance level was set at 95% ($p<0.05$) confidence interval.

Findings

The Mean score comparison

The data indicated that, the highest mean scored was a base pair symbol (BA1) with $\bar{x}$= 1.06±1.48 and the lowest was the criteria of linkage symbol between the bases (BA3) with $\bar{x}$= 0.16±0.42. As presented in *Figure 1*, about 43% got scored with correct symbolized base pair however in *Figure 2* only 14% linked the base pair with the backbone.

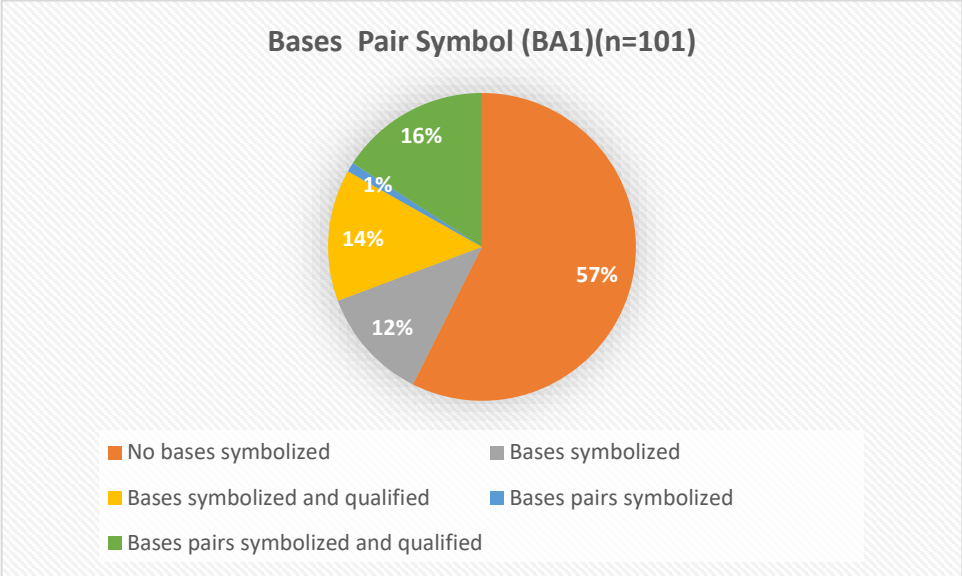

Figure 1: Base Pair symbol criteria (BA1)

DNA base composition is governed by Chargaff's rule which states the base pairing of adenine (A) with Thymine (T) and cytosine (C) with guanine (G). Correct recognition of base-pairing in DNA molecules is crucial as it serves as the foundation of RNA sequences that would leads to gene expression into proteins. However, structural DNA code is not only determined by individual base-pairs, but it is specified by the additive interactions between successive base-pairs. Ultimately this determines the overall configuration of protein molecules (Travers and Muskhelishvili, 2015). Inability of the students to correctly recognize and pairing up the nitrogenous bases indicates poor understanding regarding the primary structures of DNA.

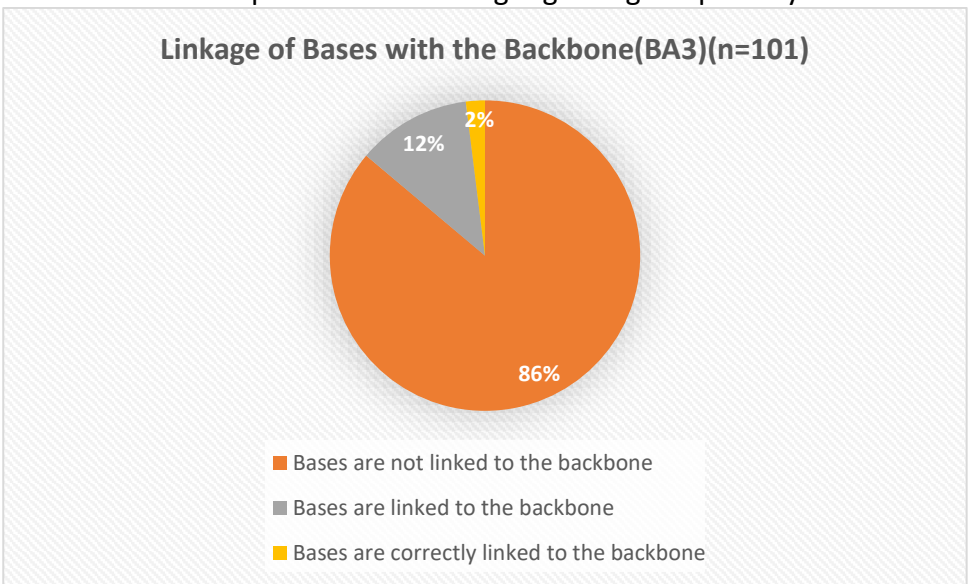

Figure 2: Base Pair Linkage to the backbone (BA3)

DNA replication and protein synthesis are part of the central dogma of molecular biology, thus understanding basic DNA structures is essential especially among undergraduate students. One of the mechanisms to evaluate students' understanding is by allowing the students to answer subjective questions that relates DNA molecular processes with structure of DNA. The scores of the students in replication, protein synthesis and genetic technology are shown in *Figure 3* and *4* respectively. About 42% of the students did not score any marks and only less than 10% of them scored full marks in replication and protein synthesis test questions. Poor understanding in DNA structures might be the main cause of the high percentage of students who were unable to answer questions related to DNA replication and protein synthesis. These processes mostly revolve around DNA and chromatin structures that play important roles such as gene expression regulation in eukaryotic cells (Minchin and Lodge, 2019). Thus, a thorough understanding about DNA structures is required in learning DNA physiological processes.

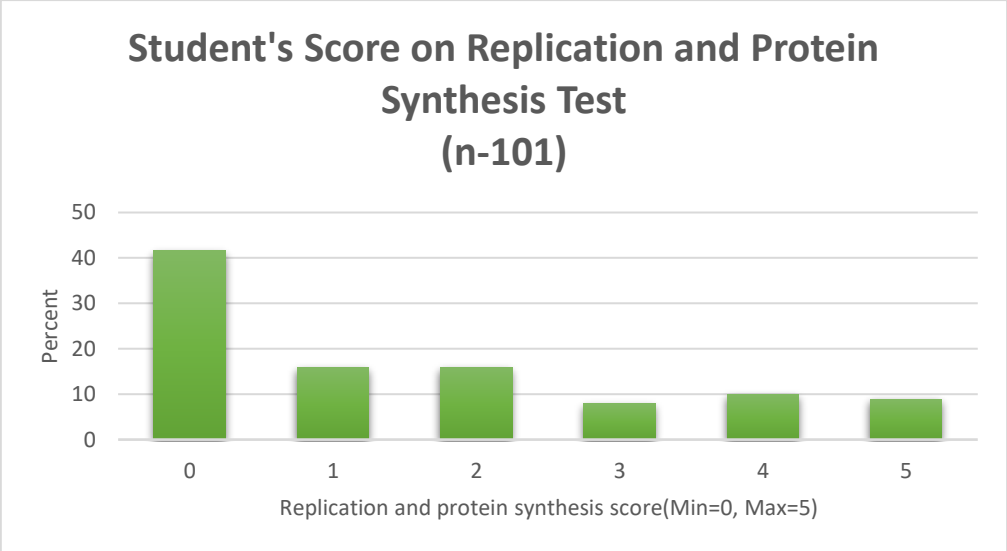

Figure 3:Replication and protein synthesis test score

For gene technology test question, students score showed better performance compared to replication and protein synthesis test. The highest percentage score was maximum mark with 22%.The mean score of test question for genetic technology was higher with 3.11±1.49 compared to test for replication and protein synthesis with 1.55±1.71. Gene technology is a multidisciplinary technology that involves genetic alterations in organisms to improve different life aspects. One of the important steps is the insertion and ligation between two different DNA fragments and produces a new recombinant DNA molecule. As this step involves physical alteration of genetic material, fundamental knowledge regarding DNA structures is mostly required (Khan et al., 2016). However, students showed better performance answering gene technology questions. Innovation and new idea are part of philosophical science which aims to improve life of modern society (Karchenko et al., 2020), nonetheless, new idea does not equal to the rise of fundamental knowledge. Questions asked in gene technology topic involving production of sticky end by restriction enzyme with given figure. Hence, students with basic base pairing ability are expected to give correct answer.

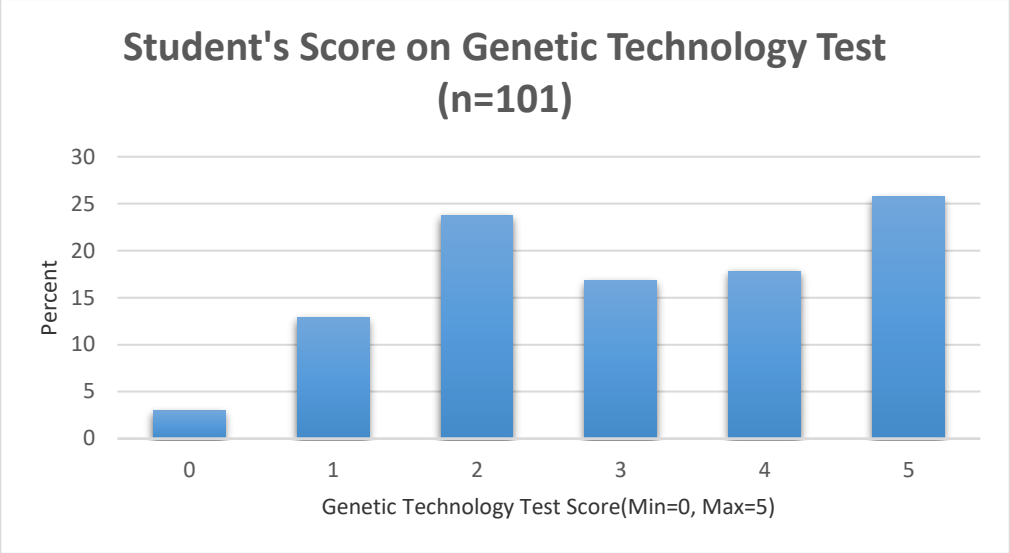

Figure 4: Gene Technology test score

The Correlation Study

Pearson correlation test as shown in Table 1 also discovered interesting fact in which a few criteria were significantly correlated to the test score of the students. (Hydrogen bond symbol between bases (BA2), deoxyribose symbol (DE) and DNA organization (OR) were significantly correlated to protein synthesis test score with (r=-0.209, P=0.036; r=0.203, P=0.042; r=-0.37, P=0.001) respectively. Besides that, the criteria such as DE, DNA primary structure- a linkage between deoxyribose and phosphate (PR2) and OR also determined to significantly correlate to genetic technology test score with (r=-0.035, P=0.001; r=0.559, P=0.001; r=0.248, P=0.012). The criteria of symbolization of hydrogen bond between the bases (BA2) as showed in Figure 5 represent the base criteria as whole to have an effect to students score in the crucial topic like replication and protein synthesis. 76% of students failed to symbolize the hydrogen bond in the diagram which depicted their lack of understanding on the base pairing concept and the presentation of DNA as a double helix strand.

Table 1
Association between the DNA structure criteria with the replication, protein synthesis and gene technology

		Replication and Protein Synthesis			Gene Technology		
	Mean±SD	Mean±SD	Pearson correlation	Sig. Two tailed	Mean±SD	Pearson correlation	Sig. Two tailed
BA1	1.06±1.48		0.121	0.228		-0.138	0.168
BA2	0.24±0.42		-0.209	0.036*		0.194	0.052
BA3	0.16±0.42		0.016	0.876		-0.044	0.663
DE	0.78±0.91		0.559	0.001*		-0.035	0.001*
PH	0.64±0.61	1.55±1.71	0.067	0.507	3.11±1.49	-0.092	0.937
PR1	0.59±0.72		-0.083	0.410		0.500	0.616
PR2	0.31±0.75		-0.174	0.082		0.203	0.042*
SE	0.36±0.74		0.126	0.209		-0.116	0.247
OR	0.49±0.88		-0.327	0.001*		0.248	0.012*

*Significant at $p<0.05$

As overall, the study reported that the criteria of bases structure of DNA have a relationship towards student's understanding on DNA replication and protein synthesis process since nitrogenous bases pairing is important in the determination of genetic code. During replication, DNA as a template for its own duplication as the nucleotide with bases A successfully pairs to T, and G with C. In this way, double-helical DNA can be copied precisely. The student's ability to determine correct base pairing will greatly influence their ability in mastering protein synthesis topic. Genetic code is an important element in protein synthesis process where its nucleotides sequence encoded specific individual amino acids from organism's genome (Hoerter & Ellis,2019). In protein synthesis process, transcription, the series of bases in DNA identifies the series of bases in mRNA due to complementary base pairing. Therefore, transcription transfers the encoded details of DNA into the series of codon in mRNA with complementary base pairing as A to U and C to G. In the following process, translation encoded details in mRNA to produce a particular series of amino acids to form the protein. The whole series of process adapted the reading and pairing of correct base sequence to finally produce protein.

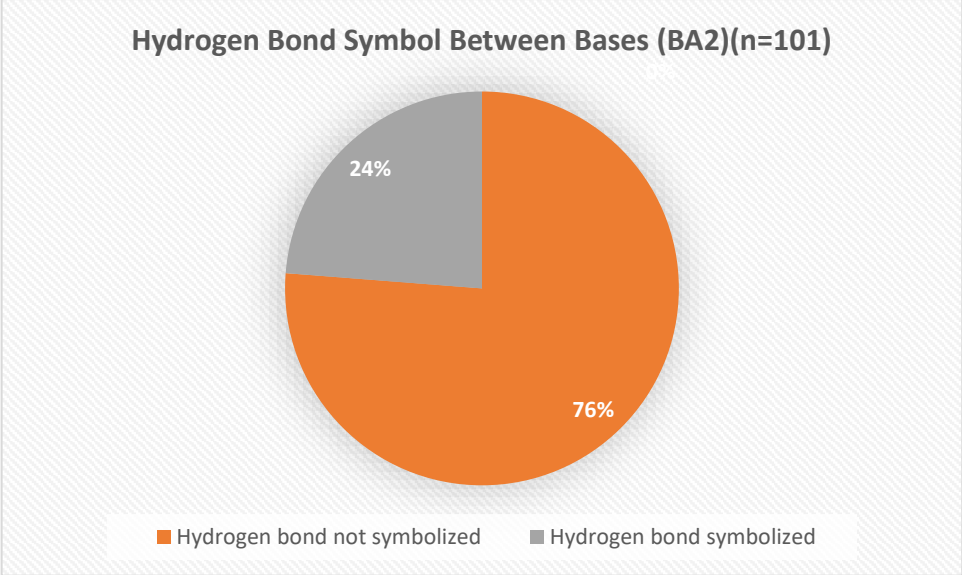

Figure 5: Hydrogen bond symbolization between the base pair (BA2)

Besides that, another crucial criterion that shown to affect both test scores were symbolization of deoxyribose (DE). As shown in *Figure 6,* 53% of respondents failed to symbolize deoxyribose in their DNA diagram. The 6-carbon deoxyribose is attached to a single phosphate group. A Schematic diagram of a nucleotide polymer by Russell (2010) shows the nucleotide is formed by bonding of a phosphate group with 5' Carbon and a base with 1' Carbon of the deoxyribose molecule. Deoxyribose is drawn in pentagonal shape while phosphate group is in circle. The nucleotides are covalently linked together in a chain through the sugars and phosphates, which thus form a “backbone” of alternating sugar-phosphate (Albert et al., 2002). Hydrogen bonds between the base portions of the nucleotides hold the two chains together as it exists in antiparallel double helix strand.

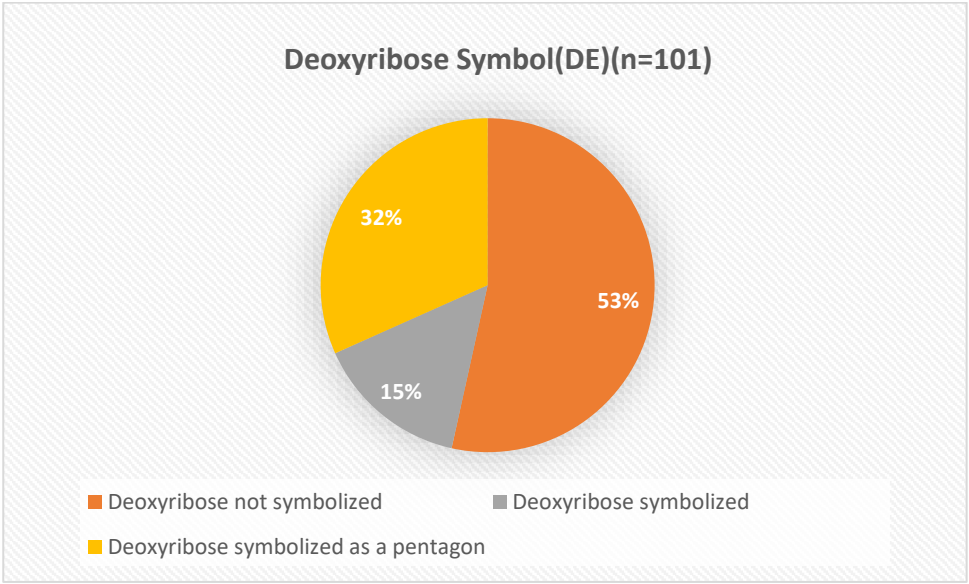

Figure 6: Deoxyribose symbolization

Less understanding on the lower level of DNA organization, starting from the basic subunit of DNA such as DNA backbone, the nucleotide can be seen further in higher level organization. The study also reported that student unable to identify the phosphodiester bond that exist between deoxyribose and phosphate group. It was shown from the criteria of identification

on DNA primary structure through a linkage between deoxyribose structure with phosphate group (PR2). PR2 also determined to significantly correlate with students score on genetic technology topic. As shown in Figure 7, 85% of students failed to define the linkage between deoxyribose and phosphate in their diagram.

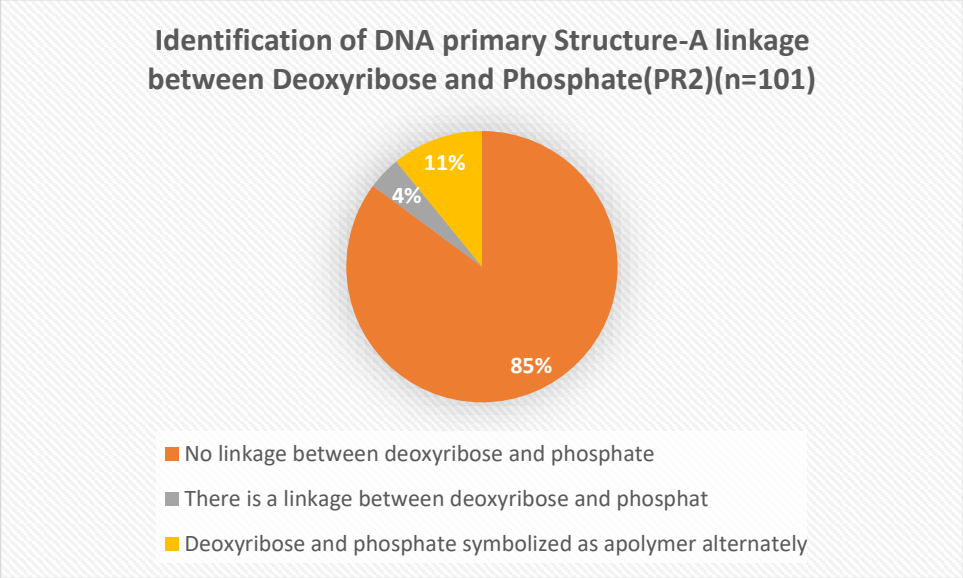

Figure 7: Identification of DNA primary structure- a linkage between deoxyribose and phosphate (PR2)

The last criteria which affect each test was understanding on the DNA organization structure (OR) as shown in *Figure 8*. As whole, 85% not well understood on the DNA organization. As considered the DNA structure from the lower organization of the simplest monomer, the nucleotide to complex three-dimensional structure of DNA, the double helix, students seem to have poor understanding on DNA structure organization.

Overall, this study discovered that the whole criteria scores, also significantly correlated to the protein synthesis test score with (r=0.238, P=0.017) but not for gene technology. As replication and protein synthesis is Students are more intrigued in learning new technologies as they can relate these new technologies with multiple aspects of daily life, not just fundamental knowledge like DNA structure. Yet, to grasp the theory and mechanical works behind new technology still requires a good fundamental knowledge.

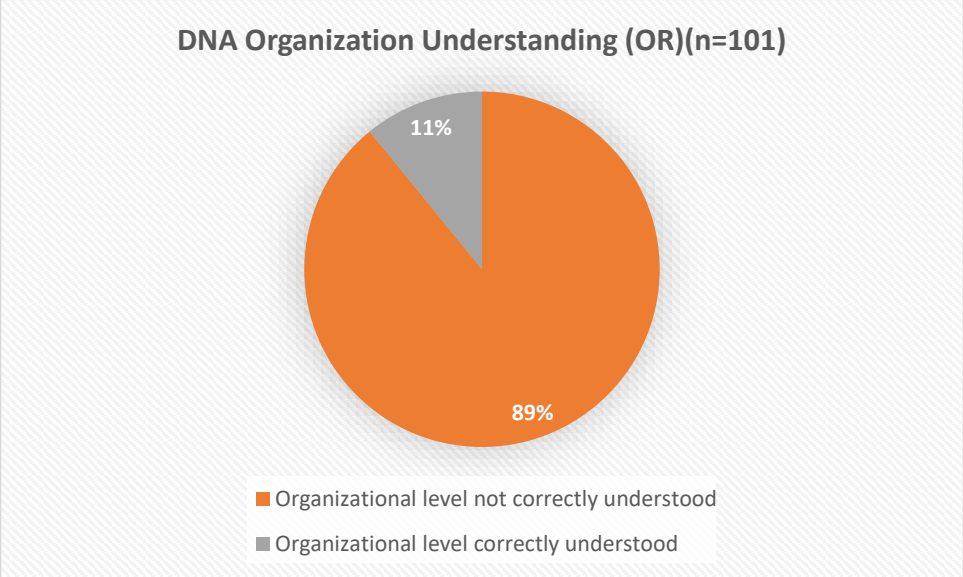

Figure 8: DNA organizational level

Conclusion

Overall, conceptual understanding on DNA structure is prerequisite to comprehend the more advanced topic in genetic. Failure on correctly visualization of DNA structure cause students to memorize the concept rather than understanding it. The root to this issue required update in teaching and learning strategy. Educators have suggested to use and develop numerous lessons that incorporate structural representations rather than using the text and reference book such as the use of structural 3D DNA model.

From this study, scientific illustration is helpful to visualise the complex fundamental concept like DNA structure. It can be used as a tool to enhance teaching and learning method while communicate the complex ideas and theories in interesting and informative way. In the context of constructivism in learning, engagement of student towards this topic can be increase using this method. Whilst, understanding and comprehension on fundamentals concept can be improved.

Reference

Avena, J. S., & Knight, J. K. (2019). Problem Solving in Genetics: Content Hints Can Help. CBE life sciences education, 18(2), ar23. https://doi.org/10.1187/cbe.18-06-0093

Cimer, A. (2012). What Makes Biology Learning Difficult and Effective: Students' Views. Educational Research Review, 7, 61-71.

DeSutter, D., & Stieff, M. (2017). Teaching students to think spatially through embodied actions: Design principles for learning environments in science, technology, engineering, and mathematics. Cognitive research: principles and implications, 2(1), 22. https://doi.org/10.1186/s41235-016-0039-y

Dudlicek, L. L., Gettig, E. A., Etzel, K. R., & Hart, T. C. (2004). Status of genetics education in US dental schools. Journal of dental education, 68(8), 809-818.

Hoerter, J. E., & Ellis, S. R. (2019). Biochemistry, Protein Synthesis. Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK545161/

Jittivadhna, K., Ruenwongsa, P., Panijpan, B. (2010) Beyond textbook illustrations: Hand-held models of ordered DNA and protein structures as 3D supplements to enhance student learning of helical biopolymers. Biochem. Mol. Biol. Educ. 38, 359–364

Khan, S., Ullah, M. W., Siddique, R., Nabi, G., Manan, S., Yousaf, M., & Hou, H. (2016). Role of Recombinant DNA Technology to Improve Life. International journal of genomics, 2016, 2405954. https://doi.org/10.1155/2016/2405954

Langheinrich, J., & Bogner, F. X. (2015). Student conceptions about the DNA structure within a hierarchical organizational level: Improvement by experiment- and computer-based outreach learning. Biochemistry and molecular biology education: a bimonthly publication of the International Union of Biochemistry and Molecular Biology, 43(6), 393–402. https://doi.org/10.1002/bmb.20888

Minchin, S., and Lodge, J. (2019) Understanding biochemistry: structure and function of nucleic acids. Essays Biochem. 63(4): 433-456. https://doi.org/10.1042%2FEBC20180038

Ozcan, N. (2003). A Group of Students' and Teachers' Perceptions with Respect to Biology Education at High School Level, MA Dissertation, Middle East Technical University, Ankara, Turkey

Russell, D. J. (2010). Modeling biological structures via abstract grammars to solve common problems in computational biology. The University of Nebraska-Lincoln.

Sandra, G., Porter, J. D., Richard, E. M., Shearn, A., Shingles, R., Fletcher, L., Murphy, S., and Pearlman, R. (2006). Exploring DNA Structure with Cn3D. CBE—Life Sciences Education. Vol. 6, 65–73.

Srivastava, A. (2015). Building mental models by dissecting physical models. Biochemistry and Molecular Biology Education, 44(1), 7–11. https://doi.org/10.1002/bmb.20921.

Tansey, J. T., Baird, T., Jr, Cox, M. M., Fox, K. M., Knight, J., Sears, D., & Bell, E. (2013). Foundational concepts and underlying theories for majors in "biochemistry and molecular biology". Biochemistry and molecular biology education : a bimonthly publication of the International Union of Biochemistry and Molecular Biology, 41(5), 289–296. https://doi.org/10.1002/bmb.20727

Tekkaya, C., Ozkan, O., & Sungur, S. (2001). Biology concepts perceived as difficult by turkish high school students. Hacettepe Universitesi Egitim Fakultesi Dergisi-hacettepe University Journal of Education, 21.

Travers, A., and Muskhelishvili, G. (2015). DNA structure and function. The FEBS Journal, 282(12), 2279-2295. https://doi.org/10.1111/febs.13307