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EVALUATION OF GENETICS KNOWLEDGE AND UNDERSTANDING AMONG UNDERGRADUATE SCIENCE STUDENTS IN DERNA, LIBYA

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ABSTRACT

With increasing the significant of genetics in daily life, it becomes necessary to pay more attention towards the subject of genetics in the school of sciences and medical institutes. The aim of the current study was to assess understanding of genetics among 115 students in majors (N= 47 students) and non-majors (N= 68 students) genetics courses and identify topics that could be challenging for them to learn. At the end of the academic year 2019-2020, undergraduate students from year two to year four at five different schools were asked 30 multiple-choice questions under six categories (Fundamentals of genetics, DNA as the genetic material, nucleic acid molecules genetic information, the central dogma outlines the flow of genetic information, genome organization, double stranded DNA forms a double helix, chromosome structure and cell division). Results showed that the average of Difficulty index (DI) values for 115 students was 0.7, 0.55, 0.43, 0.25, 0.15, and 0.51 for category 1, 2, 3, 4, 5 and 6 respectively, with genetics students had significantly higher DI value for category 2, 4 and 6 (P value <0·05) than non-genetics major participants. The study suggests that genetics is a challenging course because of its abstract nature, necessity to link information from different topics, memorizing its unique vocabularies, similarities between topics, complexity of language, confusion over phases and teaching efficacy. Overall, data presented here provided insight into factors that could make genetics a difficult course in Derna, Libya and identified topics that pose challenges for students to learn.

KEYWORDS: Genetics, non-genetics major, challenging course, difficulty, Libya.

INTRODUCTION

Biomolecular sciences include studying fields of biochemistry, molecular biology, genetics, genomics, proteomics, biotechnology and bioinformatics. Difficulties in learning and understanding concepts in biomolecular science have been studied intensively.[1-7] Although genetics is foundational course for all students aspiring for science careers, many studies identified genetics as one of the hard course.[1,4-7] Topics such as genetic material structure and function, genes, mutation, evolution, mitosis, meiosis were described as complicated topics, posing challenges for students to understand.[1,6,7] Researchers in science education suggested that confusion in learning the subject can be due to the several levels of organisation.[4,8,9] For example, Kapteijn[10] categorised the organisational levels into three categories: macro (organism) level: micro (cellular) level and molecular (biochemical) level. At the macro level students can observe macroscopic phenomena and by doing so they can gain long lasting learning experience. However, when they deal with micro and molecular phenomena they can either observe the cells under the microscope (micro level) or see the colour as an indicator for a chemical reaction (molecular level) and hence direct visual observation is restricted.[8,9]

Another reason that could prevent students from learning the subject is that students lack the ability to connect the various levels of organisation because genetic is related to different disciplines. For instance, whilst genetic traits are biological phenomena, DNA and protein synthesis, which explain the phenomena are related to the biochemistry field.[7,11,12] Furthermore, similarities between topics could also be another reason that makes genetics challenging subject.[13] For example, students found topic such as mitosis and meiosis hard to understand and comparing between them added confusion to the concepts.

Assessing difficulties in students 'understanding of genetics has received attention in many countries. However, these types of studies have not been conducted before in Libya. The aim of our study was to assess the level of knowledge and understanding of genetics among science and medical students undertaking major and non-major genetics courses in Derna, Libya and identify topics that could be challenging for them to learn. The resulting performance on these topics can assist in identifying and addressing common conceptual difficulties in genetics.

MATERIALS AND METHODS

A total of 115 students undertaking major and non-major genetics courses (47 and 68 respectively) agreed to assess their knowledge in genetics. Participants were from five different schools (medicine, pharmacy, laboratory medicine, science and genetic engineering) in Derna, Libya and they were enrolled either in year two, three or four during the academic year 2019-2020. We developed the assessment by reviewing the course syllabus and literatures to determine the learning goals for undergraduates who are doing non-major and major genetics courses, developed the assessment based on known misconceptions and major learning goals in genetics and then established six categories (Table 1). We finally created multiple-choice questions (MCQ) that could be assigned into each category. A test consisted of thirty MCQ was created using google form and sent by email to students agreed to participate in the study. To avoid guessing and to make the students comfortable answering the questions honestly we added "I am not sure" as one of the choices. In addition, all participants were asked to give their opinion about the genetics course and chose one of the following options: interesting but hard (IH), interesting and easy (IE) or boring and hard (BH). This question was not part of the thirty questions assessment. Structured one-on-one interviews with sub-sample of students (13) students at different achievement levels was conducted (Table 2). The aim of having a structured interview was to shed the light on a number of points to facilitate further analysis. Students provided answers in their own words and were allowed to elaborate on their answers if they want to do so. A full set of questions have not been provided in this article to eliminate the risk of widespread of the questions between students in the future as another assessment will be done after four years' time to identify any changes in the assessment results.

Calculations and graphs

All graphs were created using Microsoft Excel. P value was calculated using SPSS and considered significant if it's less than 0.05. The Difficulty index (DI) value for all the 30 questions for 115 students is the fraction of correct answers, which can be calculated by dividing the total number of correct responses by the total number of responses[14] and the DI for each category is the fraction of correct response for each category. This value is higher for easy questions than for difficult questions.

RESULTS

The average of DI value of exam scores of thirty questions for 115 students was 0.467. Comparing the exam scores for 47 participants studying major genetics and 68 undertaking non-major genetics courses are demonstrated in Figure 1. The average of DI of the exam scores was 0.567 for students taking major genetics course compared to 0.433 for those studying non-majors genetics course.

Identifying topics that could be challenging for students to learn was done by assigning questions into categories (Table 1). Testing students' knowledge in six genetics topics showed that DI values for 115 students was 0.7, 0.55, 0.43, 0.25, 0.15, and 0.51 for category 1, 2, 3, 4, 5 and 6 respectively, with genetics students had significantly higher DI value for category 2, 4 and 6 (P value <0·05), compared to non-genetics major participants. Interestingly, both groups scored low DI for category 5.

We also compared the DI of each question to identify a specific challenging question (Figure 3) for all 115 students, regardless of category or study field. Question 12 which was about the location of occurrence of processes involved in the Flow of genetic information" scored the lowest DI value (0.113), whereas both question 1 and question 4 which assessed students' knowledge of gene definition and mutation description respectively, had the highest DI value (0.774).

Comparison based on groups (genetics and non-genetics) showed that genetics major students found question 29 (chromosome complement definition) as the easiest question (DI value 0.94) compared with question 12 (location of occurrence of processes involved in the Flow of genetic information) and question 18 (major forms of DNA) which were the hard questions as they recorded the lowest DI value (Figure 4). In contrast, non-genetics major participants achieved the highest DI value for question 1 and question 4 under category one: basic genetics-fundamentals of genetics (Figure 5) but the lowest DI value for question 14 (Chromatin structure), question 16 (Nucleosome structure) and question 12 (the location of occurrence of processes involved in the Flow of genetic information).

We also asked the 115 students about their views on the genetics course. Results revealed that 57.4% chose genetics is interesting but hard, 35.7 % think that genetics is interesting and easy whereas 11.8% believe it's boring and hard. When we analysed the data based on groups (Figure 6), both students undertaking major and non- major genetics course equally believed that genetics is interesting but hard (57.4%) whereas genetics was interesting and easy for 42.6% and 30.9% of students doing major and non-major genetics. Interestingly, only non- major genetics group (11.8%) believed that genetics is boring and hard.

It was also interesting to interview some students to have their views on additional topics (Table 2): such as what makes genetics difficult subject, Do you read books, ask lecturers or use YouTube to understand genetics or for additional clarification. If not, what to do to understand hard topics. Students' answers are listed in Table 2. It was really interesting that most students use Youtube for further clarification. In addition, students reported that definitions, terms, complexity of the topics, imagination (micro- level of organization), similarity and differences

involved in learning the subject make genetics hard to understand.

Table 1: Course learning goals for major and non- major genetics course and corresponding questions in the assessment.

Category	Question No.
Mendlian genetics-basic genetics-fundamentals of genetics	Q1 to Q5
DNA as the Genetic Material, Nucleic Acid Molecules Genetic Information	Q6 to Q8 and Q24
The Central Dogma Outlines the Flow of Genetic Information	Q9 to Q13 and Q19 to Q23 and Q25
Genome Organization	Q14 to Q17
Double Stranded DNA Forms a Double Helix	Q18
Chromosome structure and cell division	From Q26 to Q30

Table 2: List of interview questions.

Group	Your view on genetics course	Do you study other subject related to genetics	Based on categories in the survey, what is the most difficult topic	What makes it difficult?	If you face a problem in understanding any topic in genetics, how do you deal with it? Do you seek help using books, YouTube, social media group or websites	DI of the exam
Genetics major	IE	Yes	DNA as the Genetic Material, chemical structure and double Stranded DNA Forms.	Complicated.	Ask the lecturer and try to find more information on the internet.	0.5
	IH	Yes	The Central Dogma: the Flow of Genetic Information".	Many details, remember details about gene, promoter, terminator, enhancer. etc) remember the name of proteins and enzymes for such process.	YouTube, ask genetic experts on social media groups.	0.6
	IH	Yes	Chromosome structure and cell division.	Similarity between vocabularies, a lot of definitions, confusion over phases of cell divisions.	YouTube	0.3
	IE	Yes	The Central Dogma: the Flow of Genetic Information".	Many details.	YouTube	0.46
	IH	Yes	All are easy.	-	YouTube	0.7
Non genetics major	IH	NO	Chromosome structure and division.	Lots of definitions.	YouTube	0.46
	BH	NO	All are difficult.	Complicated.	YouTube	0.36
	IH	NO	All are difficult.	So similar information yet different	YouTube	0.33
	BH	NO	All are difficult.	Similar information yet different and complicated.	YouTube	0.4
	IH	Yes	Most of them.	Need imagination.	YouTube	0.2
	IH	Yes	The Central Dogma: the Flow of Genetic Information". Cell division.	Neither easy to understand and remember, nor easy to imagine.	YouTube	0.7
	IH	Yes	Most of them.	Lots of vocabularies, similar definitions, if word in topic is ambiguous so I can't understand the rest.	YouTube	0.36
	IH	Yes	Gene expression.	Difficult to imagine the process.	YouTube	0.3

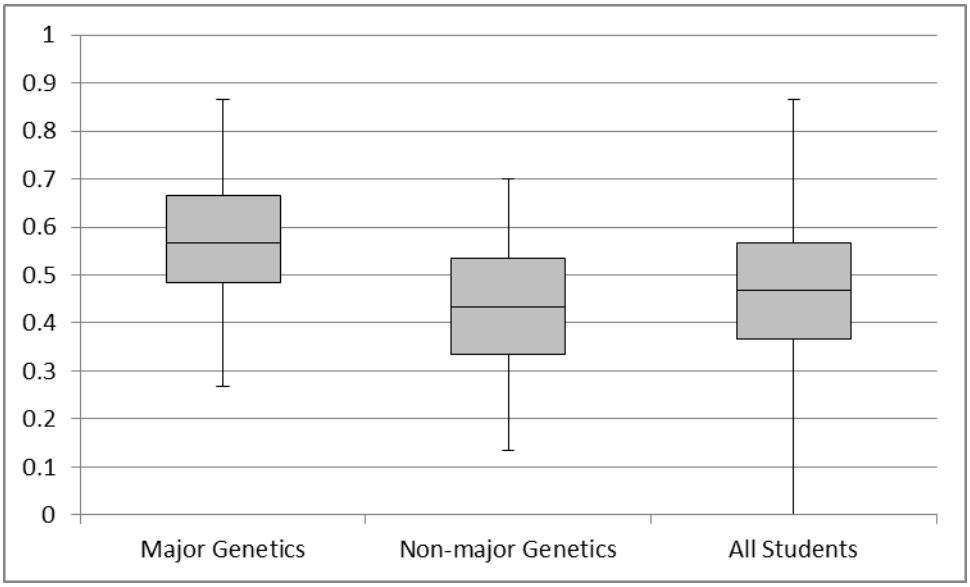

Figure 1: Box-plot of DI values of exam scores of thirty questions for 115 students, 47 genetics students and 68 non-genetics students. For each box, the lower hinge, upper hinge and inside line represent the 25th (Q1) percentile, the 75th (Q3) percentile and the median, respectively. Lower and upper bars represent the lower and the upper whiskers respectively.

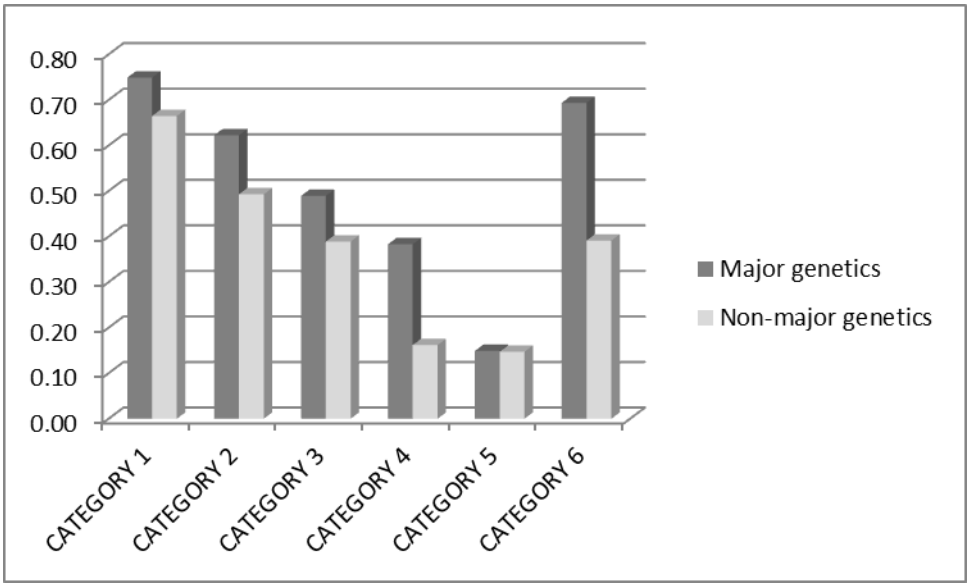

Figure 2: The difficulty index for students studying major genetics and non-majors genetics course. Genetics students had significantly higher DI value for category 2, 4 and 6 (P value <0·05). Both groups scored low DI for category 5.

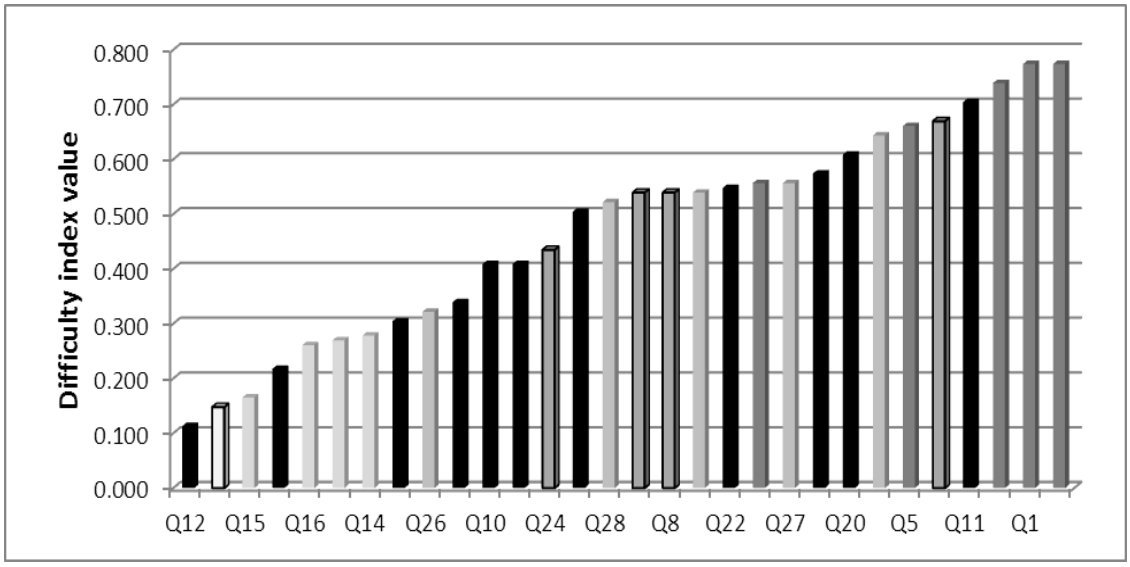

Figure 3: DI of 30 questions regardless of category or study field for all 115 students. The different coloured bars show the fraction of correct answer in each category.

■Category 3, □ Category 5, Category 4, Category 6, Category 2, Category 1

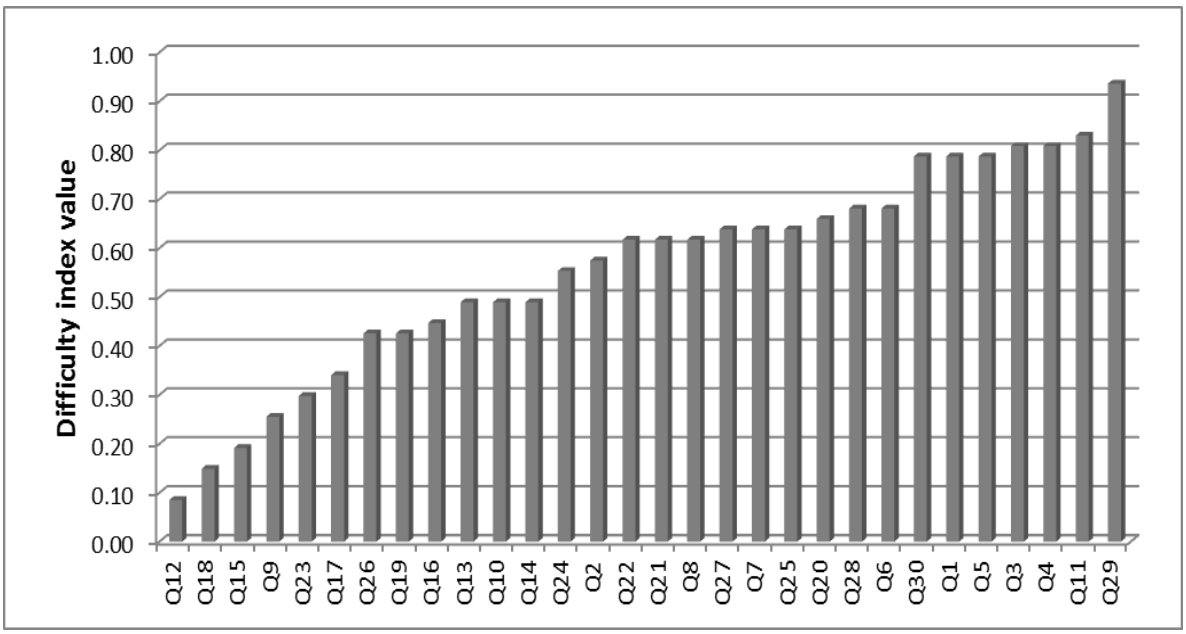

Figure 4: DI of 30 questions for 47 genetics- major students. The DI value result is the fraction of correct answers

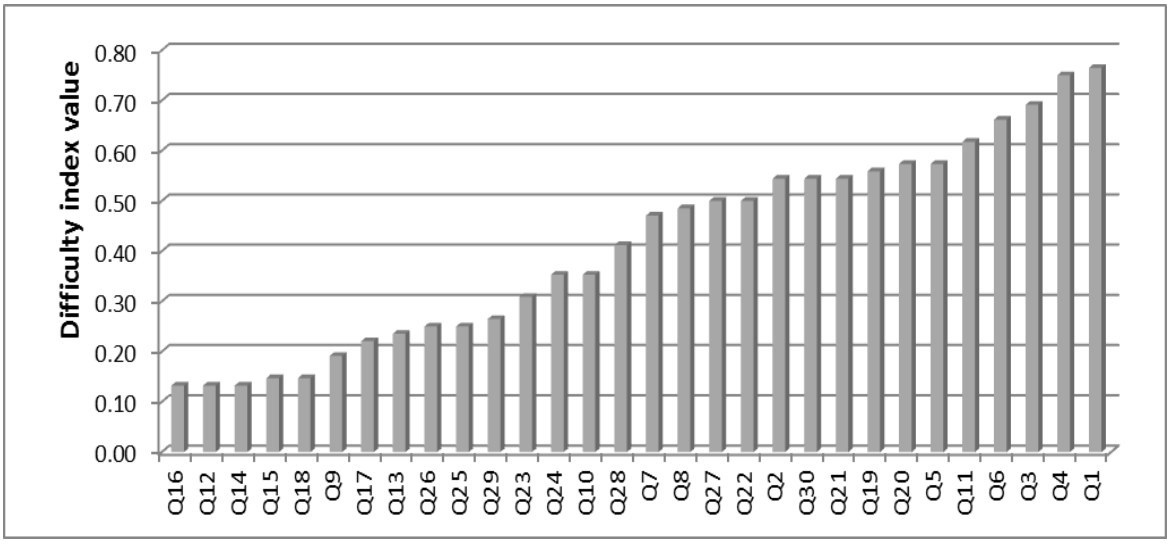

Figure 5: DI of 30 questions for 68 non-genetics major students. The DI value result is the fraction of correct answers.

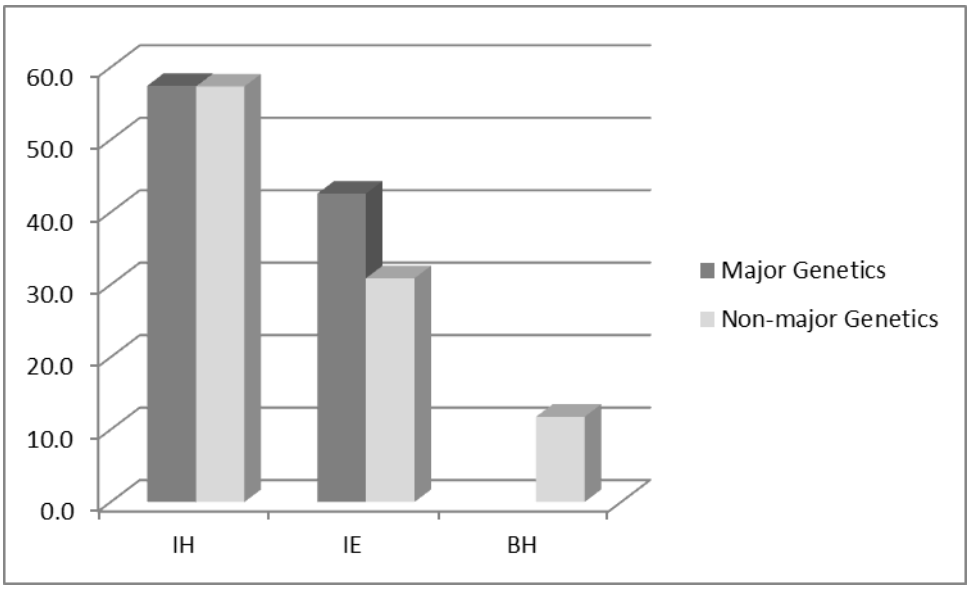

Figure 6: Students views on Genetics represented by percentage (%). Results are based on responses from 47 genetics students and 68 non- major genetics students. IH: interesting but hard to understand, IE: interesting and easy to understand, BH: boring and hard.

DISCUSSION

Our study is carried out to examine students (major and non-major genetics) understanding of genetics and some of molecular biology concepts. Analysis of participants understanding was based on their response to 30 questions that assigned into six categories, supposed to be taught in courses for both majors and non-majors genetics.

Data from our study suggested that misunderstanding of some genetics concepts was found among both majors and non-majors genetics undergraduates. In fact, the average of DI value for both students who had taken major genetics and non-majors genetics course (Figure 1) showed that even major genetics students have difficulties to answer the MCQ questions correctly. This agrees with the finding of Smith, Wood[14] who found that genetics can be a challenging subject for undergraduates, even for those who are biology majors.

Testing student's knowledge in six genetics categories revealed that most students, regardless of their majors, were able to answer questions under category one, in contrary, students scored the lowest difficulty index for category five (Figure 2). This could be due to the fact that category one covers basic genetics concepts such as definition of genes, mutations and genetics. For example, the majority of students correctly answered question 1, which asks about the term used to describe the gene "DNA that codes for a. Although most students chose the right answer, three of 115 students chose allele. Bahar, Johnstone[13] identified that students were confused between the exact meaning of allele and gene. Furthermore, Elrod[15] has found that misconception may

lead to insufficient understanding of terms such as gene/allele concepts.

Category five "Double stranded DNA forms a double helix" which assess simple factual recall rather than conceptual understanding had the lowest ID value. It is reasonable that some students did not respond to this question, since this topic was not included in their curriculum. Nonetheless, it's worth mentioning that our data could be biased since there is only one question under this category.

Analysis of findings to identify challenging questions indicated that overall, question 12, under category three, was the most challenging question, since most of students had difficulty answering it. Analysing data based on field of the study (genetics and non-genetics) showed that recall of factual information and levels of biological organization were sources of challenges for genetics major students when they tried to answer question 12 (location of occurrence of processes involved in the flow of genetic information) and question 18 (major forms of DNA).[10,16] Question 12, in particular, posed challenges for both major genetics learners and their non-major counterparts. In addition to question 12, non-genetics major students have found difficulties in answering questions 14 (Chromatin structure) and question 16 (Nucleosome structure), under category four (genome organization). In consistence with others who found that students had difficulty in understanding chromosome structure.[13,17] It seems that the difficulty in learning these topics could be associated with conceptualizing the structure, interpreting visualizations and memorizing the terms and definitions. Indeed, the lack of connection between factual and conceptual understanding can make it difficult for students to answer these questions.

Based on the face-to-face interview, most students consider genetics course as interesting but hard to understand. This is in agreement with previous studies in which students claim that science is hard to learn.[18,19] When we asked students to expand on their answers, they said 'usually attending lectures is not enough and to understand hard topics, we seek help using the Internet. Advances in virtual learning offer students the opportunity to learn complex topics and enable visualization of concepts and processes.[6]

From the six categories discussed in the paper, students were asked to choose the most challenging topic to learn, Genetics major students claimed that the most difficult topic was ''The Central Dogma: the Flow of Genetic Information". Students complained that the processes have many details, and they have to remember the names of proteins and enzymes….etc and imagine invisible steps. In agreement with Tibell and Rundgren[6] who shed the light on the importance of conceptual understanding, language, visualizations in understanding the domain of molecular life science.[6]

The other topic students claimed to be hard was chromosome structure and cell division. They explained that the similarity between meiosis and mitosis, definitions, confusion over phases of cell divisions made the topic complicated. In agreement with Bahar, Johnstone[13] who found that "meiosis and mitosis topic was one of the challenging topics for students to learn because of their similarity and teaching them side by side. Furthermore, Lewis, Leach[17] reported that students' understandings of cell division seem to be limited, wildered and changeable. Students made little differences between meiosis and mitosis and had inadequate understanding of the objective, the mechanism and the result of cell division.

The responses of non-genetics major students to the interview questions have revealed that they found difficulty to understand genetics. Most of them declared, "all topics are difficult and hard" because genetics requires imagination, has a lot of unique terms and definitions. Chu[20] stated that genetics may be recognized as a hard topic in biology, resulting in unmotivated or a tendency to give up.

Difficulties of learning experienced by students were also claimed to be related to teaching efficacy. Students claimed that some lecturers are not comfortable teaching some complex topics and therefore they consciously exclude them. Other lecturers delay the topic at the end of the semester and then excuse that no time to teach and ask the students to study the topic on their own. Consequently, students face difficulty to learn these topics on their own without instructions. Similarly, Chattopadhyay[21] reported that some genetics topics are avoided by teachers as it's difficult to explain.

CONCLUSIONS

Research on students understanding of genetics in Derna, Libya is limited. Our study was conducted to assess students' knowledge and understanding of specific genetics concepts and provide reasons for conceptual difficulties in genetics among Libyan undergraduates students. Because our study involved multiple uncontrolled variables (e.g., different faculty, student populations, lecturers, and teaching approaches), we compared students' performances based only on their field of study (major genetics or non-majors genetics). The study suggested that genetics is a challenging course because of its abstract nature, necessity to link information from different topics, memorizing its unique vocabularies, similarities between topics, complexity of language, confusion over phases and teaching efficacy. Therefore, solutions should focus on addressing difficulties reported in this study. The result may contribute to our current understanding to the difficulties and challenges faced by students studying genetics in science and medical Libyan schools.

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