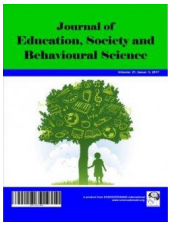

Journal of Education, Society and Behavioural Science

21(4): 1-8, 2017; Article no.JESBS.34578
Previously known as British Journal of Education, Society & Behavioural Science
ISSN: 2278-0998

Moroccan Science Student's Understanding of Meiosis and Its Relation to Gene Transmission- A Cross Sectional Study

B. Agorram[1,2*], M. Zaki[2], S. Selmaoui[1,2] and S. E. Khzami[1,2]

[1]EREF, Cadi Ayyad University, Morocco.
[2]LIRDIST, FDSDM, University of Mohamed Ben Abdellah, Fes, Morocco.

Authors' contributions

This work was carried out in collaboration between all authors. Author BA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MZ and SS managed the analyses of the study. Author SEK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JESBS/2017/34578
Editor(s):
(1) Durdane Bayram-Jacobs, Science Education and Communication Department, Faculty of Applied Sciences, Delft University of Technology, Netherlands.
Reviewers:
(1) Abdullah Aydin, Ahi Evran University, Turkey.
(2) Osman Çardak, Necmettin Erbakan University, Turkey.
(3) Mohan A. Sunkad, Karnataka Lingayat Education Society, Universiti Sains Malaysia, India.
(4) Hakan Kurt, N. E. U. Ahmet Kelesoglu Education Faculty, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/20215

Original Research Article

Received 1st June 2017
Accepted 3rd July 2017
Published 26th July 2017

ABSTRACT

Aims: This research aims to characterize the learning difficulties of students in genetics and to identify their misconceptions related to numerous concepts of genetics. It explores how students conceive meiosis and its relationship with gene transmission.
Methodology: To analyze students' understanding of meiosis and its relationship with gene transmission, we opted for a survey by questionnaire that was distributed to a sample of 384 university students were given written questionnaire. We also used the interviews to analyze in detail the learning problems of students in genetics and identify their erroneous conceptions on the subject of study (21 students).
Results: The findings would show numerous alternative conceptions about gene localization on chromosomes, meiosis process, the relationship between meiosis and Punnet square. Thus, more than one-third of the students surveyed confuse chiasma with crossing-over; or they state that all

**Corresponding author: E-mail: bagorram@gmail.com, bo.agorram@uca.ma;*

chromosomes of maternal origin migrate to one pole and paternal chromosomes to the other (14.4%) or - the two cells formed receive the same genetic information because homologous chromosomes are genetically similar (19.6%). The relationship between meiosis and genetics was not understood by students. We find also that the students' scores are low, which shows that students find difficulties in understanding the basic cytological phenomena essential to understand the transmission of hereditary traits.

Keywords: Gene transmission; meiosis; university students; misconceptions.

1. INTRODUCTION

The remarkable technological advances of today and tomorrow lead to new scientific discoveries that would improve the quality of humans' life. But they will face a number of environmental and health challenges (climate change, loss of biodiversity, mitigation of natural disasters, water management, energy, New pandemics, ..) (Carter [1]).

Science seems to be an important element in meeting these challenges and allowing humans to continue to live appropriately on Earth.

Hence the value of basic science and technology education as a universal requirement to enable people to confront these problems and avoid them being overtaken by these scientific and technological changes. The goal of Science education is not only about providing students with a basic understanding of scientific concepts, but it aims to provide them information to understand the world around them. In addition, it is also consistent with a positive attitude towards science and develops in learners a scientific culture.

Students of the 21st century must have the scientific and technological knowledge and skills that will make them members capable of making responsible decisions in their daily and professional lives and play their role effectively in a world that is constantly changing, characterized by rapid production of knowledge. To this end, they must acquire a thorough knowledge and understanding of the basic scientific and technological concepts and simultaneously demonstrate problem-solving skills and critical thinking skills in all kinds of situations (Latour [2]).

On the other hand, much research has shown that many students in developing and developed countries do not have the scientific and technological knowledge to effectively play a role in the modern world (Eisenhart, Finkel and Marion [3]).

Furthermore, the genetics education can give insight into how the living world works.

The impact of the latest genetic research on medicine, food production and health is considerable and we can say that citizens must have some understanding of the issues at stake. Therefore, the social impact of genetics on society justifies the need for all citizens to have a good conceptual understanding of genetics.

However, a literature review on student's knowledge in genetics show that students consider genetics difficult to learn and many misconceptions were identified among students. On the whole, genetics is an important topic for all learners, and this is an area where students have learning difficulties.

Several researchers have shown that high school students find difficulties in appropriating many concepts of genetics (eg DNA, RNA, gametes and genes, genetic transmission, epigenetic…etc) (Johnstone and Mahmoud [4]; Agorram et al. [5,6]; Bahar [7]; Stewart et al. [8,9]; Smith et al. [10]). For their part, Knippels et al. [11] identified some types of learning difficulties in genetics. Among the causes mentioned are (a) the vocabulary and the specific terminology, (b) the content and analysis processes used in genetics, (c) the cytological processes involved, (d) the abstract and complex nature of genetics.

According to Duncan and Reiser [12], genetics are difficult to understand due to lack of perception of the genes responsible of hereditary characteristics. In addition, genetics requires abstract thinking. It is one of the reasons for the difficulty of understanding genetics.

To understand gene transmission, many cytological processes were involved as mitosis, meiosis, crossing-over…These concepts were taught in other disciplines as cellular biology, animal biology…

Cell division is one of the most difficult topics to teach in biology and life science in secondary schools. Teachers claim meiosis to be the most difficult part of cell division to teach to their students (Oztap et al. [13]; Smith [14]; Kindfield, [15]). It has also been reported that misconceptions pupils hold in meiosis make it more difficult to solve genetics problems, particularly monohybrid and dihybrid crosses (Brown [16]).

Students have difficulty distinguishing between mitosis and meiosis and between somatic and germ lines. Students don't understand the role that meiosis plays in heredity (Goff et al. [17]; Lewis et al. [18]; Flores et al. [19]).

The aims of the study are to analyze university students' understanding of meiosis and its relationship with gene transmission.

The main question of the study is the following: Do university students understand meiosis and its relationship with gene transmission?

2. METHODOLOGY

For data collection, we used the questionnaire. Semi-structured interviews allow us to better analyze the results of the questionnaire.

2.1 Sample of Students

The study was conducted with a sample composed of 384 students (52.1% female and 47.9% males). The average age is 22 years (standard deviation 1.812). Participants prepare for Bachelors in Biology and have already received a genetic education. They previously had studied cell division and meiosis in cytology, genetics, and molecular biology, during various semesters.

2.2 The Questionnaire

The questionnaire was developed taking into account literature work, including "The Genetics Concept Assessment (GCA)" (Smith et al. [10]). It's a tool for assessing the knowledge of genetic students. We adapted it to the context of our research by adding several questions that were not dealt with in this questionnaire.

The questionnaire used is subdivided into three sections: The first section refers to personal questions (age, gender, ...), the second section deals with the perceptions of students about the teaching of genetics and the difficulties encountered and the third section includes questions assessing the students' knowledge of various themes of genetics.

We also structured the questionnaire in such a way as to have logical blocks (grouped by themes) so that the students are not disturbed by the scattering of the questions of the same theme, as well as to be able to judge the coherence of the conceptions of the students on the same theme.

The questionnaire was administered to students at the end of a course in the presence of a researcher. The filling time of the questionnaire is 1 h 30 min.

For the analysis of student responses, the number of correct and incorrect answers was counted. Some questions accept several correct answers, others only one correct answer.

To obtain a complete score, the student must check all relevant proposals only. The student understands most of the relevant proposals, but not all of them, and no irrelevant proposals, which leads to a lower score. If the student indicates some or all of the relevant proposals with other irrelevant ones, he will get an even smaller score. Finally, the student omits all relevant proposals and only indicates irrelevant propositions and thus obtains a negative or zero score.

To obtain a score for each question, we used the formula:

$$\text{Score} = \frac{\text{The number of correct boxes chosen}}{\text{Total number of correct boxes}} - \frac{\text{The number of incorrect boxes chosen}}{\text{Total number of incorrect boxes}}$$

The score of a student could range from -1 to +1 (Egan [20]).

2.3 The Interview

The interview took place with 21 students. We have developed a grid for interview. The questions focused on numerous concepts related to Mendelian genetics. We had asked students to draw a pair of genes on chromosomes in prophase I and show their segregation during meiosis.

3. RESULTS AND DISCUSSION

We will analyze part of the questionnaire (7 questions) and the results of the interviews.

The percentages were calculated on the basis of the number of students who answered the question (non-respondents are not included in the calculation).

Q20. Which of the following proposals concerning meiosis is INCORRECT?

1. Meiosis occurs only in sexually propagated species.
2. It divides the number of chromosomes in reproductive cells.
3. It leads to genetic variation in offspring.
4. It occurs in most cells of the body at some point during the life of the individual.
5. It maintains the number of chromosomes constant from generation to generation.

About four out of ten students (40.6%) correctly stated that meiosis does not occur in most cells of the body at some point during the life of the individual. It occurs only in the germ cells to produce the gametes.

About two out of ten students (18%) believe that meiosis occurs in sexually and asexually reproduced species. 6.5% of students report that meiosis does not divide the number of chromosomes in reproductive cells in half. Other students (8.3%) believe that meiosis does not keep the number of chromosomes constant from generation to age (Table 1).

Q28. The separation of the alleles occurs during:

1. Prophase I
2. Télophase II
3. Metaphase I
4. Aanaphase I

This question concerns the meiosis phase during which the alleles separate. More than one third of students (37.4%) reported that this separation occurred during anaphase I, 5.2% indicated that it occurs during prophase I, 14.9% during telophase II and 41.6% during metaphase I.

This shows that students confuse the different stages of meiosis and associated genetic processes.

Q29. When homologous chromosomes are joined together to form tetrads during meiosis, two chromatids, one of each chromosome, can exchange DNA segments. This phenomenon bears the name of:

1. Chiasma
2. Crossing-over
3. Genetic Independence
4. Epistasis

Table 1. Students' answers to question 29

Proposals		Number	Valid percentage
Valid	1	123	32,5
	2	237	62,7
	3	3	,8
	4	12	3,2
	12	3	,8
	Total	378	100,0
Total		385	

(N.B: 12 means that student has checked the boxes 1 and 2)

Crossing-over is the exchange of genetic material between homologous chromosomes during meiosis, it is a very important event because it allows an interchromosomic stirring that increases the genetic variability.

Regarding this, only 62.7% of students recognize this cytological phenomenon while 32.5% confuse the crossing-over with the chiasma concept. The two sister chromatids (of the same chromosome) are connected by centromere, the two homologous chromosomes are connected to the level of the chiasmas which can be numerous. It is at this level that the nodules of recombination cut to realize the crossing over. Crossing over is the action of exchanging portions between chromosomes of the pair, it takes place during the zygotene stage of prophase I (Table 1).

Q30. When is there crossing-over?

1. When genes are linked
2. When the genes are independent
3. In both cases

About half of the students (47.8%) say crossing-over occurs when genes are linked, others (17.3%) report that crossing-over occurs in the case of independent genes and 34.6% opt for both case (Table 2).

When one has a crossing over, it is that the two genes are physically linked that is to say located on the same chromosome. When there is no crossing over, the two genetic sites are not on the same chromosome, so they are physically and genetically independent. So if two genes are physically independent (located on different chromosomes), there is no crossing over possible. But there is a small subtlety, in the case where we have two sites, located on the same chromosome, but very distant, the frequency of crossing-over is going to be very high (close to 50% which is the maximum). The results of crosses show that we are dealing with independent genes (located on two different chromosomes), but in fact they are on the same chromosome; simply, their frequency of recombination is so high that they behave as if they were independent. So students must grasp the difference between physical and genetic independence.

Table 2. Students' answers to question 30

Proposals		Number	Valid percentage
Valid	1	182	47,8
	2	66	17,3
	3	132	34,6
	12	1	,3
	Total	381	100,0

(N.B: 12 means that student has checked the boxes 1 and 2)

This is important because the understanding of genetic inheritance laws require that these concepts are understood by students. Solving genetic problems also requires the assimilation by the students of the difference between dependent and linked genes and cytological phenomena underlying.

Q40. The first division of meiosis allows the separation of homologous chromosomes:

1. All chromosomes of maternal origin migrate to one pole and the chromosomes from paternal origin to the other one.
2. The random separation of chromosomes of paternal and maternal origin is responsible for a mixing of the alleles of different gene.
3. The homologous chromosomes which separate are all formed of two chromatids
4. The two cells formed receive the same genetic information because the homologous chromosomes are genetically similar.

This question 40 relates to meiosis. Only 5.7% of the students gave a complete correct answer, others provided a correct partial answer (47.5%).

Again, it is possible to identify erroneous conceptions such as: - all chromosomes of maternal origin migrate to one pole and paternal chromosomes to the other (14.4%) or - the two cells formed receive the same Genetic information because homologous chromosomes are genetically similar (19.6%) (Table 3).

Table 3. Students' answers to question 40

Proposals		Number	Valid percentage
Valid	1	55	14,4
	2	108	28,2
	3	74	19,3
	4	75	19,6
	12	12	3,1
	13	13	3,4
	14	14	3,7
	23	22	5,7
	24	10	2,6
	Total	383	100,0

(N.B: 14 means that student has checked the boxes 1 and 4)

Q42. Meiosis:

1. Performs an interchromosomal brewing by randomly constituting batches of chromosomes whose number alone is imposed.
2. Is the cause of an intrachromosomal brewing because exchanges occur between homologous chromosomes?
3. Produces, from an initial genotype, a multitude of gametes with identical genotypes.
4. Systematically collects in the haploid cells the alleles of each gene.

Question 42 concerns also meiosis. Here again, erroneous conceptions can be identified such as: - meiosis produces from a genotype a multitude of gametes with identical genotypes (20.6%) or - meiosis systematically collects in the haploid cells the alleles of each gene (18.8%) (Table 4).

Q48. The breeding of genetic information during meiosis is caused by:

1. The random distribution of homologous chromosomes between the daughter cells.
2. The random distribution of all chromosomes between the daughter cells.

3. The existence of exchanges of chromosomal segments between non-homologous chromosomes.
4. The existence of exchanges of chromosomal segments between homologous chromosomes.

Table 4. Students' answers to question 42

Proposals		Number	Valid percentage
Valid	1	60	15,7
	2	137	35,8
	3	79	20,6
	4	72	18,8
	13	3	,8
	14	3	,8
	23	8	2,1
	24	21	5,4
	Total	383	100,0

(N.B: 14 means that student has checked the boxes 1 and 4)

Meanwhile, 22.5% of students report that genetic mixing during meiosis is caused by the random distribution of all chromosomes between the daughter cells; 22% of them state that this mixing during meiosis is due to the exchange of chromosomal segments between non-homologous chromosomes. This is false because the origin of mixing during meiosis is due to the random distribution of homologous chromosomes between the daughter cells (13.9%), and the existence of exchanges of chromosomal segments between the homologous chromosomes (41, 6%) (Table 5).

This shows once again the existence of erroneous conceptions on several cytological and genetic aspects of meiosis.

Table 5. Students' answers to question 48

Proposals		Number	Valid percentage
Valid	1	53	13,9
	2	86	22,5
	3	84	22,0
	4	159	41,6
	Total	382	100,0

We find that the students' scores are low, which shows that students find difficulties in understanding these notions relating to meiosis, crossing-over (ie the basic cytological phenomena essential to understand the transmission of hereditary traits).

To diagnose sources of student's confusion, we had ask students to outline the behavior of a pair of genes during meiosis.

Below, we will present some examples of erroneous conceptions identified by the analysis of student's answers during interviews.

Some students locate alleles of the same gene on different sites of the homologous chromosomes, which is incorrect because the alleles of a gene are always located on the same site or locus. They also schematize a crossing-over between the alleles of the same gene (pair B1/B2) (Fig. 1).

Automatically, the result of meiosis will be false. According to the scheme of student A6 for example, we would obtain a gamete with two alleles of the same gene instead of obtaining a single copy of each gene.

Table 6. Main score by question

Question	Q20	Q28	Q29	Q30	Q40	Q42	Q48
Main score	0.38	0.18	0.51	0.22	0.06	0.06	0.05

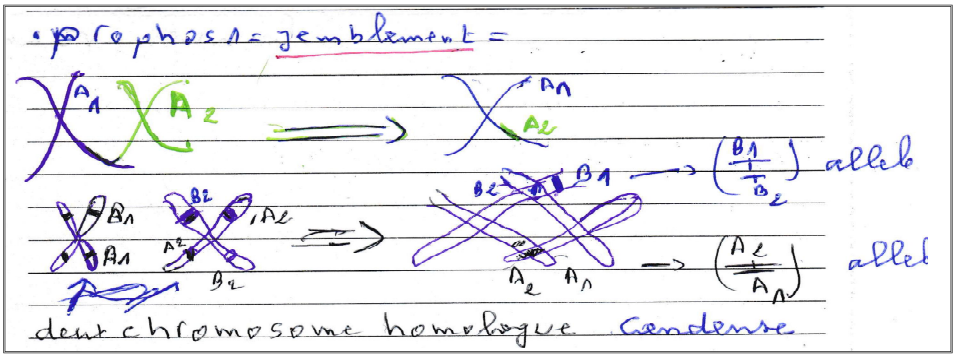

Fig. 1. Diagram of chromosomes in prophase 1 according to the student A6

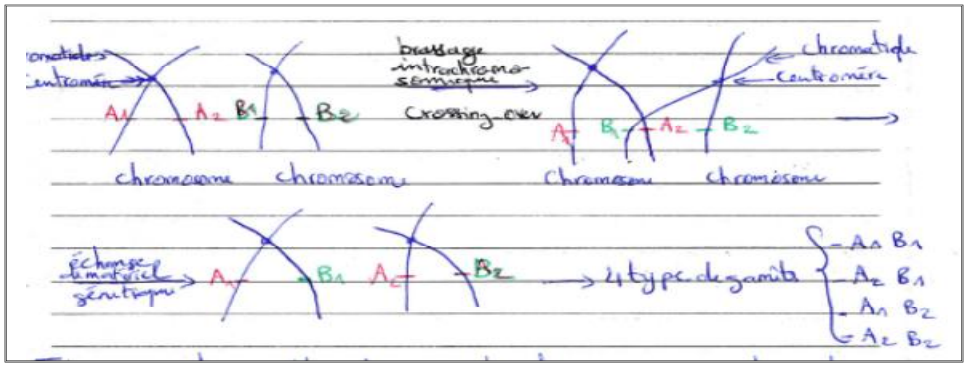

Fig. 2. Diagram of chromosomes in prophase 1 according to the student A9

We report below some of the arguments provided by student A6 to explain the above diagram.

- Researcher: What do the letters A1 and A2 mean?
- Student A6: alleles of gene A.
- Researcher: you have marked them on the same chromosome on the different loci (after the arrow).
- Student A6: yes because there was a mixing between the initial chromosomes
- Researcher: you have marked a chromosome with 4 alleles (4 letters A1, A2, B1, B2)
- Student A6: because it's a heterozygote
- Researcher: what is the result obtained
- Student A6: two types of gametes
- Researcher: So, the gamete contains the alleles of the same gene (A1 and A2)?
- Student A6: yes, the other gamete contains the alleles B1 and B2.
- Researcher: But A1 and A2 are the alleles of the same gene
- Student A6: yes, but every gamete contains a gene, not the both.

The same errors are found in the diagram of student A9.

The alleles of two different genes are located on the same site of the chromosome (Fig. 2).

These examples are not an exception but a fairly common occurrence among students.

These erroneous conceptions are partly due to the difficulties encountered by students in cytological aspects related to genetics, such as meiosis and consequent genetic shuffling.

The students do not link these cytological aspects with the genetic aspects.

4. CONCLUSION

Meiosis is a topic that generates learning difficulties among students. These do not often include the cytological aspects of meiosis (succession of stages, differences between meiosis I and II, ...) nor the relation of these cytological aspects with genetics. Thus, students do not assimilate well the behavior of the chromosomes during meiosis, the different types of mixing during meiosis, the crossing-over phenomenon, the random disjoining of independent genes and the segregation of linked genes. The students do not mobilize this knowledge when they have to explain the results of genetic crosses, especially when they schematize the segregation of a pair of alleles in the form of a Punett square.

These difficulties encountered by students in meiosis have already been cited by other researchers in other countries (Mills et al. [21], Lewis et al. [18]).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Carter L. Globalisation and science education: Rethinking science education reforms. Journal of Research in Science Teaching. 2005;42(6):561-580.
2. Latour B. La science en action. Introduction à la Sociologie des Sciences, La Découverte. 2005;664. French
3. Eisenhart M, Finkel E, Marion SF. Creating the conditions for scientific literacy: A re-examination. American

Educational Research Journal. 1996;33: 261–295.
4. Johnstone AH, Mahmoud NA. Isolating topics of high perceived difficulty in school biology. Journal of Biological Education. 1980;14(2):163-166.
5. Agorram B, Clement P, Selmaoui S, Khzami SE, Chafik J, Chiadli A. University students' conceptions about the concept of gene, interest of an historical approach. Journal of US-China Education Review. 2010;7:2.
6. Agorram B, Zaki M, Selmaoui S, Khzami SE. Interaction of genotype and environnment in expression of phenotype: do university students integrate knowledge about epigenetics in Education Research Highlights in Mathematics, Science and Technology. USA, ISRES Publishing, International Society for Research in Education and Science; 2016. (ISRES) ISBN: 978-605669501-8
7. Bahar M, Johnstone AH, Hansell MH. Revisiting learning difficulties in biology. J Biol Educ. 1999;33(2):84-86.
8. Stewart J, Hafner R, Johnson S, Finkel E. Science as models building: Computers and high school genetics. Educational Psychologist. 1999;27(3):317-336.
9. Stewart J, Rudolph JL. Considering the nature of scientific problems when designing science curricula. Science Education. 2001;85(3):207-222.
10. Smith MK, Wood WB, Knight JK. The genetics concept assessment: A new concept inventory for gauging student understanding of genetics. CBE Life Sciences Education. 2008;7(4):422–430.
11. Knippels MC, Waarlo AJ, Boersma KT. Design criteria for learning and teaching genetics. Journal of Biological Education. 2005;108-112. DOI: 10.1080/00219266.2005.9655976
12. Duncan RG, Reiser BJ. Reasoning across ontologically distinct levels: Students' understanding of molecular genetics. Journal of research in Science Teaching. 2007;44(7):938-959.
13. Oztap H, Ozay E, Oztap F. Teaching cell division to secondary school students: An investigation of difficulties experienced by Turkish teachers. Journal of Biological Education. 2003;38(1):13-15.
14. Smith M. Teaching cell division: Student difficulties and teaching recommendations. Journal of College Science Teaching. 1991;21(1):28-33.
15. Kindfield ACH. Understanding a basic biological process: Expert and novice models of meiosis. Science Education. 1994;78(3):255-283.
16. Brown CR. Some misconceptions in meiosis shown by students responding to an advanced level practical examination question in biology. Journal of Biological Education. 1990;24(3):182-186.
17. Goff EE, Reindl KM, Johnson C, McClean P, Offerdahl EG, Schroeder NL, White AR. Efficacy of a meiosis learning module developed for the virtual cell animation collection. CBE—Life Sciences Education. 2017;16(9):1–12.
18. Lewis J, Leach J, Wood-Robinson C. What's in a cell?—Young people's understanding of the genetic relationship between cells, within an individual. J Biol Educ. 2000;34(3):129–132. DOI: 10.1080/00219266.2000.9655702
19. Flores F, Tovar M, Gallegos L. Representation of the cell and its processes in high school students: An integrated view. Int. J. Sci. Edu. 2003; 25(2):269-286.
20. Egan K. Structural communication – A new contribution to pedagogy. Programmed Learning and Educational Technology. 1972;1:63-78.
21. Mills Shaw KR, Van Horne K, Zhang H, Boughman J. Essay contest reveals misconceptions of high school students in genetics content. Genetics. 2008;178(3): 1157–1168.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20215