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# Turkish Middle School Students' Difficulties in Learning Genetics Concepts

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## ABSTRACT

The purpose of this study is to reveal middle school students' difficulties in learning genetics concepts. Both quantitative and qualitative research approaches were used in the present study. Survey method was used to explore the students' difficulties in conceptual and procedural level. An open-ended questionnaire was conducted to find out students' difficulties in learning genetics. Moreover, basic interpretive qualitative research approach was used in the present study. Parallel with this approach, a semi-structured interview was conducted to find out the students' difficulties comprehensively. The number of students that participated in this study was 128 from two elementary schools in Izmir-Turkey. The determined major difficulties in learning genetics were the function of cell and chromosome concepts. When we ask the functions of genetics concepts instead of their definition, most of the students had difficulty to explain the functions of these concepts. In general, students memorized the concepts of genetics. In addition to conceptual difficulties, some procedural difficulties in genetics were also explored. Regarding transfer of genetics information, when 62.6 % of the students answered the related question correctly, 41.6 % of the students did not develop true reasoning about this process. The difficulties related to teaching methods, textbooks, and mathematical expressions were other difficulties determined in this study.

**Keywords**: Learning Difficulties; Genetics Concepts; Middle School Students.

## INTRODUCTION

Science education researchers have presented the argument in which the students have difficulty in learning some science concepts. In this perspective, identifying students' difficulties in science learning has received a big attention in science education research (Beeth, 1998). The researchers explored that one of the most difficult content areas in science was genetics (Lewis & Wood-Robinson, 2000; Wynne, Stewart, & Passmore, 2001; Marbach-Ad & Stavy, 2000; Marbach-Ad, 2001; Cakır & Crawford, 2001; Law & Lee, 2004; Lewis, Leach, & Wood-Robinson, 2000a; 2000b; 2000c; 2000d). Duncan and Reiser (2007) asked the question that why learning genetics phenomena so difficult for the learners? Two answers were developed for this question in the literature. The first one is that students have difficulties in the invisibility and inaccessibility of genetics concepts. The second one is that genetics included complicated structure. Genetics involved multiple biological organization levels—genes, proteins, cells, tissues, organs, etc (Duncan & Reiser, 2007). Previous studies supported this claim that the main genetics concepts which were hard to learn by students were gene, gamete, allele gene, mitosis and meiosis,

monohybrid and dihybrid crosses and linkage (Bahar, 2002; Bahar, Johnstone & Hansell, 1999; Law & Lee, 2004; Tsui & Treagust, 2003). Especially similar genetics topics were confused by the students. For example, students had confusion between mitosis and meiosis topics (Bahar, Johnstone & Hansell, 1999). In addition to difficulty in learning of these genetics concepts, Cavallo and Schafer (1994) stated that many students (10th grade) did not construct necessary relationships among these genetics concepts, and had the problems about the process and the mechanism of inheritance (Bahar, Johnstone & Sutcliffe, 1999; Cavallo, 1996; Friedrichsen & Stone, 2004; Lewis & Wood-Robinson, 2000; Lewis & Kattmann, 2004; Lewis et al., 2000a; 2000d; Marbach-Ad, 2001; Wynne et al., 2001). Another problem mostly determined in the literature was mathematical expressions in learning genetics because these expressions caused problems and the genetics symbols (e.g., XX, XY) were not used consistently by teachers and textbook writers.

## METHODOLOGY

Both quantitative and qualitative research approaches were used in the present study. As a quantitative approach, survey method was used to explore the students' difficulties in conceptual and procedural level. An open-ended questionnaire was conducted to find out students' difficulties in learning genetics. The researchers also used basic interpretive qualitative research approach for the present study (Merriam & Associates, 2002). Parallel with this approach, a semi-structured interview was conducted to find out the students' difficulties in learning genetics comprehensively.

### a) Sample

The sample was 128 middle school students (62 male and 66 female), ages between 14 and 15 years, attending in two public schools in İzmir (Turkey). Two-stage random sampling (Fraenkel & Wallen, 2006) sampling method was used to select schools and classes respectively. Two schools among the İzmir-Buca elementary schools were selected, and then three 8th grade classes were selected from these schools. Each class approximately has 20 students. With 10 students, drawn from just two schools, took part in the interview. The main criterion for selection of the students for the interview was that the students should be willing to contribute. In addition, their achievement in the questionnaire is considered. Low (3 students), middle (4 students), and high (3 students) achievers were selected.

### b) Instrumentation

A questionnaire with open-ended questions and a semi-structural interview protocol were utilized to collect data from the students.

#### i) Open-ended Questionnaire

Using the data from the relevant literature (Lewis & Wood-Robinson, 2000; Lewis et al., 2000a; 2000b; 2000c; 2000d), an open-ended questionnaire was developed. The questions in the questionnaire consisted of five items. Three items which are the functions of genetics concepts, comparison of somatic and sex cells, and size relationship of genetics concepts were based on Lewis and Wood-Robinson's (2000) questions. The other two items which were related to transfer of genetic information and the effect of environment on genetics were developed by the researchers. All of the questions were open-ended that it was believed these questions may be more effective in revealing students' in-depth thinking. Content validity of each item in the test was determined by one expert in the

Biology Department, two experts in Biology Education Department and two experts in the Measurement and Evaluation Department. As a result of the pilot study which was conducted with 30 students, it was determined that there was no need to change any items in the open-ended questions. Open-ended questions were answered within one lesson; in approximately 50 minutes.

**ii) Semi-structured Interview**

In addition to open-ended written questions, qualitative data was collected from students by using semi-structured interviewing method. Interview questions were adapted from Aydın's (1999) questions. A group of total 10 students from 8th grade were interviewed. Interview questions covered four areas which are the functions and comparison of genetic concepts and the size relationship among the genetics concepts, Mendelian genetics, effect of environment on genetics, general difficulties in learning genetics (e. g., textbooks, teaching methods, learning environments).

Each individual interview lasted approximately 20 minutes, and was recorded and later transcribed verbatim. Participants' ideas were explored in a manner consistent with inductive data analysis as described by Lincoln and Guba (1985). To achieve this, the first author read all transcripts taking notes regarding patterns that emerged from each participant. The second author examined three randomly selected transcripts to establish consistency between two categorizations. The rate of agreement between the two authors in categorizing for each of the three transcripts exceeded 85%. Because of this high rate of inter-rater agreement, the rest of the transcripts were categorized by the first author of the present study.

## FINDINGS

### *a) Students Understanding of the Main Genetics Concepts*

To explore students' difficulties in genetics concepts, two questions were asked in the open-ended questionnaire. In response to first question, students wrote the genetic structures (cell, nucleus, chromosome, DNA, gene) in order of size from largest to smallest. Genetic structures from largest to smallest were correctly ranked by 84% of the students. In addition, 16% of the students did not correctly rank the genetics structures. In response to second question, students wrote these genetics structures' function. Regarding students' understandings of cell concept, four different categories (correct response, incorrect response, defined concepts, and not response) were obtained from students' answers. When 62.5% of the students defined the cell concept, only 14% of the students correctly explained the function of cell. It can be said that students might not have deep understanding about the cell's function.

Another issue explored during the interviews was about the function of chromosome. The majority of the students said that they had not understood the function of chromosome. Only 5% of the students have explained the function of chromosome correctly. An example of a dialog with student 7 supported this claim. When the interviewer asked "why are chromosomes so important?" the student claimed that "I really don't know why they are so important".

Regarding the function of DNA, a majority of the students (57%) explained the function of DNA correctly. An excerpt with student 1 supported this claim. The question "If a living thing doesn't have DNA, what kind of problems will reveal?" was asked to student 1, and then s/he answered the question like this; "DNA carries our hereditary features. If we didn't have such hereditary features, our features wouldn't pass to our offspring and our features wouldn't exist."

Regarding the function of gene, when 35% of the students explained the function of correctly, above the %50 of the students did not explain. Thus, the students had difficulty in the understanding of gene concept correctly. The interview conducted with student 2 supported this claim. When the interviewer asked "where are genes found in our body and what is the importance of gene for living things?" the student answered these questions respectively that "they are found on the part of DNA and genes determine the structure of an organism. If genes don't exist, organism will not be developed".

***b) Students Understanding of the Characteristics of Somatic and Sex Cells***

To explore students` understanding regarding characteristics of somatic and sex cells, the comparisons of three types of cells in terms of their genetics characteristics were asked to the students.

In the first question, the genetic characteristics of Mehmet's two cheek cells were asked. This question was explained by 73.5 % of the students correctly (but correct reasoning was done by only 36.7 % of the student). In the second question, the genetic characteristics of Mehmet's cheek cell and nerve cell was asked. This question was explained by 41.3 % of the students correctly (but correct reasoning was done by only 21 % of the students). In the third question, the genetic characteristics of Mehmet's cheek cell and sperms cell was asked. This question was explained by 60.1 % of the students correctly (but correct reasoning was done by only 31.3 % of the students. In the fourth question, the genetic characteristics of Mehmet's two sperms cells were asked. This question was explained by 40.7 % of the students correctly (but correct reasoning was done by only 25% of the students). In addition, when we analyze these four questions, some misconceptions were explored about the structure and the function of somatic and sex cells. For example, several students claimed that the genetic structure of cheek and nerve cells are different because their functions are different, and they are taken from different locations of body. They also claimed that the genetic structures of cheek and sperm cell are different because their functions are different.

***c) Students' Difficulties in Understanding the Transfer of Genetic Information***

In order to explore students' understanding regarding the transfer of genetic information, the question related to the transfer of the blood groups of five families was asked. The main aim of this question was to explore the extent which the students understand the transfer of genetic characteristics (blood groups) and the genotype concept.

This question was correctly explained by 62.6 % of the students (but correct reasoning was done by only 41.6 % of the students).

***d) Students' Difficulties in Understanding of Sex Determination***

To explore students' understanding related to sex determination, the question which is "a family has three daughters, what would be the sex of the fourth children? Please explain the reason of your answer" was asked to students. This question was correctly answered by 62.6% of the students (but correct reasoning was done by only 48 % of the students). It can be understood from interviews that most of the students can explain the effect of heredity on sex correctly.

***e) Students' Difficulties in Understanding the Effect of Environment on Genetics***

To explore students' understanding of the effect of the environment on genetics, some genetic cases related to the effect of environment on genetics were given to students, and wanted to explain these cases with some genetics concepts (Mutation, Modification,

Natural Selection, or Adaptation). Related to these genetics concepts, above 70% of the students did not have any problem about understanding of these concepts.

In addition, when we analyze interviews, some misconceptions were explored about these concepts. For example several students claimed that an offspring of a blind cat having accident can't be blind. The reason of this is modification because modifications are not hereditary. They also claimed that if one of the animal group lives in productive area, the number of this group increase; if this animal group lives in unproductive areas, the number of this group becomes less, this can be given as an example to the modification.

***f) Students' Difficulties related to Textbooks***

As a result of the interviews, it was explored that there were serious problems about science textbooks. It was revealed that these textbooks did not give the essence of the subject and did not have enough exercises. In addition, one of the reasons for students not being pleased with textbooks was that students may not reach enough conceptual knowledge for solving genetics problems in these textbooks. Also, most of the students select test book (exercise book) because these books have a lot of exercises and explain the concepts of the subject briefly and prepare students for future exams.

***g) Students' Difficulties related to teaching Methods***

The result of interviews showed that students generally were pleased with the methods the teachers used. It was said that, after they learn concepts, they solve problems but they wanted more exercises and visual activities. They believed that if teachers do more practice exercises and use some visual aids during teaching activities they will learn genetics concepts better.

***h) Students' Difficulties Related to Mathematics Expressions***

In open-ended questions, there was not any problem about mathematical expression but interview results indicated that students have difficulties about mathematical expression, especially, in mono-dihybrit linkages.

## DISCUSSION and IMPLICATIONS

The questionnaire and the interview results indicate that Turkish middle school students have several difficulties in learning genetics. One of the biggest problems students have they did generally not conceptualize the genetics concepts. Instead of this, they generally memorized these concepts. They easily defined the genetics concepts. However, when we asked the function of these genetics concepts, and their reason of answer, they mostly failed to explain reason of their answer. In addition to the functions of genetics concepts, students had difficulty in the size relationships among genetics concepts. Similar results were found in Lewis and Wood-Robinson's (2000) study that one quarter of their sample showed genes are larger than chromosomes. In the present study, another determined difficulty in learning genetics concepts was related to process including transfer of genetic information. Although most of the students answered the question of transfer of genetic information correctly, their reasoning was mostly not correct. This result was supported by Lewis and Wood-Robinson's (2000) study that they claimed there was widespread uncertainty as to how genetic information is transferred from cell to cell within organism. In addition to these conceptual and procedural difficulties in genetics learning, students revealed general difficulties related to textbooks and mathematical expressions. A majority of the students specified that they are mostly

using test books instead of textbooks because they claimed that textbooks are very boring and include lots of activities.

Duncan and Reiser (2007) stated that students have learning difficulties in genetics concepts because these micro-level concepts are invisible and inaccessible. At this point, we can recommend that curriculum should follow the process in which the flowing ought to be from macro-level concepts such as cell, cell division to micro-level concepts such as chromosome and genes. Kılıç, Atav, Sağlam (2006) suggested that if the concepts related to somatic and sex cells is taught first, in future the learning of these concepts will construct a basis to learn genetics concepts more easily. In Turkish Middle School Science curriculum (Tebligler Dergisi, 2000; 2005), genetics topic have taken precedence of cell division topic. Depending on the results of the present study, we can recommend that at first cell division topic should be taught, and then genetics topic should be taught. If students understand cell division process well, genetics concepts and process may be more understandable and concrete for students. In addition to Turkish Middle School Science curriculum, when we look at the England curriculum, Lewis and Wood-Robinson (2000) stated that "the England curriculum is very prescriptive, the subject matter which it covers is extensive and the time available to teach is limited." We can mention similar problems in Turkish Science Curriculum in which there are lots of complicated concepts and processes in genetics topic. However, the time for the teaching of this concepts are rather less. Thus, our second recommendation is giving more time to teach genetics concepts and procedures in Turkish Science Curriculum. Moreover, similar to other Western and US countries (Venville, Gribble & Donovan, 2005), genetics may be taught in the high school levels because students' thinking skills may be more appropriate for learning these abstract and complicated concepts at this level. As a result, the precedence and timing schedule of genetics in science curriculum should be re-considered by science curriculum and policy makers. The third recommendation is related to teaching materials for the genetics concepts and procedures. If the teachers use vehicles to provide more visibility and accessibility, the genetics concepts may be more understandable for the students. For example, simulations, animations, tutorials and games may be developed and used in classrooms for the clear representation of genetic concepts. Some previous studies (Law & Lee, 2004; Tsui & Treagust, 2003; Corn, Pittendrigh & Orvis, 2004) used the computer-assisted instruction, and they claimed that this method may be useful for visual representation and conceptualization of genetics concepts.

It is striking that in the science education literature; previous studies were conducted in high school and college levels. This study made a contribution into science education literature the way using the sample of middle school students. Thus, the consensus in which genetics is hard topic in order to conceptualize is provided with respect to middle school, high school and college level students. Furthermore, previous research on students' difficulties were conducted generally in Western and USA countries (Wynne et al., 2001; Marbach-Ad & Stavy, 2000; Marbach-Ad, 2001; Law & Lee, 2004; Lewis et al., 2000a; Duncan & Reiser, 2007). Few past research studies (e.g., Kılıc et al., 2006) have considered the issue of "learning difficulties in genetics" in a developing country such as Turkey. Turkey may be called as a bridging country between east and west, and it carries both east and west social norms. Thus, "learning difficulties in genetics data" in the Turkish setting provides a new perspective between issues of East and West. Thus, like other Western and USA countries, the claim of genetics is hard topic is highly supported by the present study.

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