Secondary School Students' Alternative Conceptions about Genetics

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Abstract

Alternative conceptions are considered to be the dominant factor in hindering students' learning in Science. The aim of this study was to explore 11th grade students' alternative conceptions of concepts related to genetics and heredity. A sample of 186 students from Riyadh city, Kingdom of Saudi Arabia, was randomly selected and given a valid and reliable written questionnaire. The results indicated that students hold many alternative conceptions about concepts related to genetics and heredity, involving direct and indirect cell division, reduction division, sexual and asexual reproduction, and the process of genetic information transfer. Specifically, the findings revealed that students have difficulty in differentiating between asexual and sexual reproduction, and also that there is a lack in students' understanding of the mechanisms of transferring genetics and heredity characteristics in reproduction and cell division. As a result, these types of alternative conceptions may have weakened students' ability to explain their answers to the written questions. Such alternative conceptions may, in fact, hinder students' understanding of most of the biological concepts.

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Introduction

Genetics is the science that examines the nature and behaviour of the genes, and the fundamental hereditary units (The American Heritage, 2009). It is also defined as the study of biological inheritance (McClean, 2000; Joshua, and Yun, 2010), because it deals with a wide variety of inherited traits, from the ability to bear large numbers of fruit in trees, to eye colour in mammals. It is the study of how DNA is passed down from one generation to the next. Genetics and heredity include difficult concepts in the biology curricula at the primary and secondary school (Hallden, 1988; Kelly and Monger, 1974; Longden, 1982) and even at college and university levels (Brumby, 1979, 1984; Johnston and Mahmoud, 1980; Kindfield, 1994a, b).

Meanwhile, genetics education has become increasingly important with the advent of recombinant DNA technologies and the subsequent emergence and availability of genetically modified food and organisms (GMOs). Scientific understanding of genetics and genome is important for the comprehension of all types of diseases (Spradling, et al. 2006), because it can lead to better diagnosis and treatment. In addition, social workers need to understand genetics and inheritance to help them understand how social, behavioural, cultural, economic, and environmental factors interact with biological factors to influence health. The inclusion of the basic conceptual framework for understanding the concepts related to hereditary information and the basic mechanisms involved in the evolution of living beings (Chattopadhyay, 2005; Banet and Ayuso, 2003; Lewis et al. 2000c) would also help students to understand the biological significance of certain phenomena such as cell division, and reproduction. Students' lack of understanding about genetic relationships is the main obstacle to building a 'coherent conceptual framework'. To understand genetics, students require knowledge about the structure and function of the cell and its organelles, and about cell division and reproduction.

Recent studies have shown that the understanding of genetics and its various aspects is poor among students of various levels and among the population in general (Lewis & Wood-Robinson, 2000; Lewis, Leach & Wood-Robinson, 2000a, b, c; Lock and Miles, 1993; Lock, Miles & Hughes, 1995; Marbach-Ad, 2001; Marbach-Ad and Stavy, 2000; Michie et al., 1995; Scriver, 1993; Wood-Robinson, 1994, 1995). Studies indicated also that students of all ages have difficulty understanding heredity and genetics, and reproduction concepts. Stewart, Hafner and Dale (1990) asserted that the absence of a comprehension of underlying genetic mechanisms hinders students' ability to solve genetics problems in any meaningful way. Learners might invent a 're-understanding' of the various concepts as they are required in their own world. This type of understanding is referred to as inter alia, alternative conceptions or naïve ideas. Therefore, it is important to identify students' alternative conceptions, especially in genetics and heredity.

Poor understanding, misconception or alternative conception of concepts such as genetics can be explained through different theoretical frameworks. First, the concept of genetics can be characterized as abstract. Abstract concepts are hard to understand, which may in turn cause alternative conceptions which are hard to change. Students need to have high operational abilities in order to understand abstract concepts (Piaget, 1952; Piaget, 1964; Piaget, 1971). Second, meaningful learning of biological concepts would enable students to apply knowledge in their future life. Ausubel (1968; 2000) indicated that effective learning involves constructing conceptual understanding in a meaningful way. He suggested that 'meaningful learning takes place if the learning task can be related in a non-arbitrary, substantive (non-verbatim) fashion to what the learner already knows'. On the other hand, in his learning theory, Novak, (1990) proposed that an individual's cognitive framework is organized in a hierarchical manner with concepts linked proportionally from more general and inclusive to more specific and less inclusive. He added that meaningful learning requires a deliberate effort on the part of the learner to link new knowledge to prior constructs or as a meaningful learning. Ausubel also suggested "meaningful learning takes place if the learning task can be related in a non-arbitrary, substantive (non-verbatim) fashion to what the learner already knows" (Ausubel, 1968, p. 24).

Alternative conceptions can be defined as false or non-scientific beliefs held by students on a specific concept or phenomenon, which may be caused by their misunderstanding of other subjects or gained from their earlier experiences. Alternative conception can be referred to as misconception, naive conception, or pre-instructional conception, because they all describe the same phenomenon in which a learner has a strong commitment to an idea or explanation that differs from the scientific conception (Bahar, 2003; Wandersee et al., 1994). Alternative conceptions are mostly persistent, well-embedded in an individual's cognitive ecology, and, therefore are difficult to 'teach away,' especially by didactic methods. As a result, alternative conceptions represent a real barrier to students' understanding of biology (Takkaya, 2002; Saka, et al. 2006).

Current research studies have paid much attention to alternative conceptions, particularly in biology. For example, a study by Lewis and Wood-Robinson (2000) investigated the knowledge and understanding of genetics among secondary students in the UK, and they found that secondary students have little understanding of the process of information transfer. In addition, they found that students lack the basic knowledge about genes, chromosomes, and cells. Chattopadhyay (2005) also studied Indian higher secondary school students' understanding of genetics information related to cells and the transmission of genetic information during reproduction. Also He used the questionnaire developed by Wood-Robinson (2000) for the collection of the data. The results indicated that students lacked the basic understanding of genetics. He argued that Indian students' misconception of genetics may be related to the fact that the way biological subjects are taught in schools requires students only to memorize concepts and factual information, rather than meaningfully understand them. Min-Nan, Kun-Chang and Ti-Chu (2007) investigated the effect of grade level, gender, and school location factors on Taiwanese high school students' conceptual learning of biology. To fulfil this goal, 4,537 students were randomly selected from ten districts in Taiwan, and a questionnaire on biological concepts was applied to the sample students. The one-way ANOVA and t-test analysis of the data have shown that students in the urban areas had clear and better biology conceptions than students in eastern Taiwan and other distant districts. Ninth grade students performed better than 8th grade students. No significant difference in conceptions related to gender was found.

Student's alternative conceptions of genetics and other abstract biological concepts are found in Saudi Arabia. For example, Shahrani (1995), and Nashiri (2008), argued that despite the existence of both global and local studies about genetics and inheritance, which proved that students hold these alternative conceptions, there is still a great need to see how Arab students understand concepts related to genetics. A study was conducted by Mustafa (1996) on the patterns of alternative conceptions about diversity in living organisms held by 10th grade students. He found that textbooks, teachers, and the surrounding environment are among the main sources of such misconceptions. Similar claims are also reported by Shahrani's study (1995), which concentrated on 11th grade Saudi students' understanding of concepts related to inheritance; she found that students' understanding of inheritance is poor and they held many alternative conceptions about the inheritance of characteristics that are acquired from the environment.

Addressing students' alternative conceptions in genetics and heredity is important, especially to students in Saudi Arabia and the rest of the Arab world, because it might lead to uncovering the factors, including socio-cultural factors, which, in addition to the abstract nature and the lack of meaningfulness of such concepts, may affect the specific student's understanding of science concepts in general and biological concepts such as genetics and inheritance in particular. Socio-cultural factors might affect students' conceptions, especially about controversial concepts such as those related to genetics and heredity. According to the socio-cultural perspectives of the worldview theory, the mind is not isolated from social and cultural contexts. Therefore, the construction of knowledge, which starts from concrete experiences, forms abstract concepts, then goes back to the concrete, results from the dynamic interplay between the mind and the external environment (Kearney, 1984). Therefore, the worldview becomes an implicit organization of the mind. He suggested that the worldview comprises seven universals that are interconnected, interdependent, and common to different cultures. He calls this model of the worldview the logicostructural model of universals. On the other hand Cobern (1995) proposed that science education should be perceived as an endeavor whereby students embark into a worldview of foreign rather than internal affairs. As a result, teaching controversial concepts such as genetics at the secondary level should take into account that students have different views, other than the tentative scientific views. Cobern, (1996) stated that instructors should first probe into students' worldviews and presuppositions about universals, which constitutes the first step toward understanding and appreciating various worldviews, and then handle their ideas from a merely rational conceptual change perspective that tacitly assumes the superiority of scientific concepts over other ideas.

In relation to controversial issues, two studies (Dagher and BouJaoude, 1997, 2005; Hokayem and BouJaoude, 2008) investigated the nature of Lebanese college biology majors' accommodation of the theory of evolution with their existing religious beliefs. The studies classified students into those accepting the theory, those rejecting it, those who reinterpreted it, and those who were neutral. They found that individuals who study the theory in depth would have an advantage of considering more arguments while trying to formulate their positions. Specifically, Hokayem and BouJaoude (2008) probed students' epistemological beliefs or some of their worldview presuppositions such as causality; one of the universals according to the worldview theory. Causality constitutes a cornerstone of scientific reasoning; hence, probing students' presuppositions of causality may help gain insight into their preference of scientific or other types of causality and allow researchers to relate someone's position about a scientific theory, such as evolution, to his or her causality preference. Hokayem and BouJaoude, (2008, p. 6), argued that "probing students' views of nature is another way to gain insight into how they regard themselves and how that relates to their views of evolution because evolution takes place in nature". They added that "investigating students' presuppositions such as causality and nature in addition to their views about science and religion helps in constructing a more complete picture of how students relate evolution to their worldview".

In addition, alternative conception includes views learned by students from sources other than scientific education, such as mythical teachings. Similarly, everyday experiences may cause alternative conceptions of some biological concepts, especially in Saudi Arabia. For example, Mendel's studies emphasized that genes could behave independently from each other during transmission to offspring. Now, it is known that genes are transmitted as constituents of chromosomes, each of which carries many different genes, which sheds light on the tendency of certain characteristics to appear in combination with one another (linkage). Conceptual misunderstandings arise (Miller et al., 2007; Mintzes, Wandersee & Novak, 1998, 2002; Mintzes, et al. 1991) when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and non-scientific beliefs. To deal with their confusion, students construct faulty models that are usually so weak that the students themselves are insecure about the concepts. Vernacular misconceptions are words (e.g., 'work') that have a meaning in everyday life different from the scientific one.

The teaching of genetics represents unique challenges to educators, because of the abstract nature of concepts related to the subject. For instance, concepts such as direct and indirect cell division, sexual and asexual reproduction, and the process of genetic information transfer can be problematic to instil. The problems associated with learning these concepts in high schools and universities are often put down to the linear order in which they appear in the textbooks and the didactic nature of instruction (Kindfield, 1994a, b; Longden, 1982; Mitchell and Lawson, 1988; Pearson and Hughes, 1986; Stewart, 1982; Brown, 1995; Cho, Kahle & Nordland, 1985; Smith and Sims, 1992; Kinnear, J, 1983). In addition, alternative conceptions held by teachers may have a strong relationship to students' conceptions. For example, Boo (2005) conducted a study to highlight Singapore teachers' misconceptions of biological concepts through the analysis of their biology test papers. The results showed that the questions in the test papers included many types of misconceptions of biological concepts, such as breathing and respiration, plant reproduction, cell structure and mechanisms, and human systems. Misconceptions of cell division and the structuring of biological concepts held by biology teachers were also investigated by Dikmenli (2010). The researcher used drawing and interview strategies for the identification of biology teachers' misconceptions of those biological concepts. A sample of 124 biology teachers was involved in the study. The results revealed that biology teachers hold a series of misconceptions and problems related to cell division and structuring concepts. It was also revealed that teachers confused the stages of the cell division processes and the events occurring during these stages.

Genetics and heredity are considered among the essential concepts for students at middle and secondary school level. According to the Biology High School Learning Standards and Benchmarks (Massachusetts Biology High School Standards Public Comment Draft, 2006), students at the middle and secondary level have to explore and understand structure and function in living systems, reproduction and heredity and genetics, regulation and behaviour, populations and ecosystems, and diversity and adaptations of organisms. They should understand the role of reproduction, heredity and genetics for all living things. They should also be able to identify and relate the interactions of populations of organisms within an ecosystem. Therefore, understanding heredity and genetics in general is fundamental to understanding modern biology. In addition, high school instruction should include such concepts because the understanding of genetics deepens students' understanding of the biological sciences, and increases their knowledge of the human genome, new tests for genetic disorders, and gives them new tools to solve crimes, should that be their future career. Every day the field of genetics is growing as scientists find new and novel ways of applying the methods and technology that modern molecular genetics has given us.

In this study we are shedding light on students' misunderstanding and alternative conceptions of genetics concepts, such as: indirect cell division, reduction cell division, and reproduction and the process of genetic information transfer. The assumption is that this study would reflect the knowledge and understanding of indirect cell division, reduction cell division, reproduction and the process of genetic information transfer which secondary students would be taking with them into their future academic life. We intend to produce baseline data which might be of use to those interested in science curriculum development and to biology teachers, and to biology programming designers.

Background

Education in Saudi Arabia is centrally regulated and controlled by the ministry of education. The educational system consists of three stages: the elementary stage consists of six years, the middle stage consists of three years, and the secondary stage also consists of three years. Biology is taught in all grades in the three stages, and is considered to be compulsory. In the elementary and middle schools, biology is taught as a part of the general science course. In the secondary schools, there are four independent science courses: biology, chemistry, physics, and geology. These courses are required for all students in the first grade of the secondary stage; however, for the second and third grades of this stage, these courses are compulsory only for the scientific track students. Concepts related to genetics and inheritance are taught to 11th grade Saudi students in the first semester (the first half of the academic year).

Studies assured that the inclusion of genetics in the middle and secondary schools (Deadman and Kelly, 1978; Engel Clough and Wood-Robinson, 1985) is of great importance because it is the cornerstone of modern biology and a critical aspect of scientific literacy. On the other hand, Marbach-Ad and Stavy (2000) indicated that the misunderstanding of genetics persists at school, college, and university levels. Studies (Lewis et al. 2000a, b, c; and Marbach-Ad, 2001) proved that the concepts in genetics are ‘compartmentalized’ and ‘without providing any conceptual framework,’ which could be a result of teaching methodology. The inclusion of the basic conceptual framework for understanding the concepts related to genetics, hereditary information and the basic mechanisms involved in the evolution of living beings (Chattopadhyay, 2005; Banet and Ayuso, 2003; Lewis et al. 2000c) would help students to understand the biological significance of certain phenomena such as cell division, and reproduction. It would also help students understand genetic relationships, the lack of which is the main obstacle to building a 'coherent conceptual framework'.

On the other hand, certain topics in biology, such as genetics, genetic engineering, and heredity, as well as bioethical questions, the theories of evolution, the big bang, have certain controversial implications when taught in the classroom. Some of these topics are opposed on a religious basis especially by illiterate sections of the general population. Saudi students' understanding of biological concepts might be affected by their culture. The culture of society in Saudi Arabia is strongly affected by their knowledge, and both are guided by their religion, Islam. The socio-cultural perspectives of the worldview theory assert that the mind is not isolated from social and cultural contexts. Therefore, the construction of knowledge, which starts from concrete experiences, forms abstract concepts, then goes back to the concrete, results from the dynamic interplay between the mind and the external environment (Kearney, 1984). Therefore, the worldview becomes an implicit organization of the mind. Kearney suggested that the worldview comprises seven universals that are interconnected, interdependent, and common to different cultures.

Methodology

Purpose

The purpose of this study was to investigate Saudi secondary students' understanding of biological concepts related to cell division, reduction division, reproduction, and genetic information transfer. The research questions that guided the study were:

- What is the nature of 11th grade students' conception of direct and indirect cell division and reduction division?
- What is the nature of 11th grade students' conception of asexual and sexual reproduction in animals and plants?
- What is the nature of 11th grade students' conception of the relationship between reproduction and genetic information transfer from one generation to another?

Subjects

Three secondary schools were randomly selected from Riyadh city, KSA. Then, two classes were randomly selected from each school. As a result, 186 11th grade students formed the sample of the study. Table1 includes the distribution of the study subjects.

Table .1
Distribution of the study subjects

School	# of Classes	# of Students
1	2	65
2	2	59
3	2	62
Total	6	186

The Questionnaire Used

In this study we used a questionnaire, developed by Lewis et al. (2000a, c) as part of the Learning in Science Research Group, Leeds University (United Kingdom). The questionnaire includes two parts: the Cells section and the Reproduction section. It combines both fixed- and free answer–type questions. Even though the questionnaire was used in the United Kingdom for middle school children, the same questionnaire was used for higher secondary students in India (Chattopadhyay, 2005). The use of the questionnaire in this study was justified because it had been prepared by an experienced research group working in genetics education and had already been tested among students (Lewis and Wood-Robinson, 2000; Lewis et al., 2000a, b, c). It was administered also to high school students in India (Chattopadhyay, 2005).

The questionnaire was translated into the Arabic language with permission from the author. To ensure that the meaning of the original manuscript was preserved, a back translation of the questionnaire was done by a special translator separate from the researchers. The questionnaire includes questions related to the following concepts: Indirect cell division, Sexual reproduction, Asexual reproduction, and Genetic information transfer genetics, because these concepts are included in the 11th grade biology textbook.

In addition, the translated version of the questionnaire was given to science education experts from the department of curriculum and instruction, in the college of education, and the department of biology in the college of science at King Saud University. It was also given to high school biology teachers for content inspection. The questionnaire was literally modified according to the experts' comments. In addition, we used Cronbach's alpha reliability test to determine the reliability of the translated version of the questionnaire. It was found that the questionnaire is reliable at 0.83. The modified Arabic version of the questionnaire was then applied to 11th grade students after their biology course. Then the data were analyzed by using the descriptive statistics. Frequencies and the percentages were then calculated because they are suitable for this kind of data.

Results

To determine the nature of students' conceptions, we used frequencies and percentages of the appearance of the wrong alternatives among students in the sample. If the percentage of the frequency of the wrong alternative is 25% or more, we consider that students hold alternative conceptions about the concept. There are two types of students' answers; the first type is their choice from several alternatives (multiple choice). The second type is a written response, where students were required to justify or write a reason for their choices, for each question. In this section the results are presented according to the order of the study questions, as follows:

The first question was about cell division. It includes two parts: the first part asks about cell division for growth and repair, while the second asks about cell division for the reproduction of sex cells. The results of data analysis of students' answers to the first part of the question, which is related to students' understanding of cell division for growth and repair, are presented in Table 2.

Table 2
Result of students' understanding of cell division for growth and repair (Question 1 part 1)

Question	Answer alternatives	n	%
In animals, when skin cells divide, how many new skin cells are produced?	8 chromosomes	28	15.1
	4 chromosomes*	95	51.0
	2 chromosomes	15	8.1
	Don't know	48	25.8
Student's reasons**	No answer	122	65.6
	Correct reason	64	34.4
Would the original skin cells and the new skin cells contain the same or different genetics?	Same genetics*	125	67.2
	Different genetics	30	16.1
	Don't know	31	16.7

Student's reasons**	No answer	103	55.4
	Correct reason	83	44.6
Would the muscle cells divide in the same way?	Yes*	113	60.7
	No	45	24.2
	Don't know	28	15.1
Would the testis cells divide in the same way?	Yes*	71	38.2
	No	92	49.5
	Don't know	23	12.3
Would the egg cells divide in the same way?	Yes*	56	30.1
	No	85	45.7
	Don't know	45	24.2
Would the kidney cells divide in the same way?	Yes*	105	56.5
	No	48	25.8
	Don't know	33	17.7
Would the stomach cells divide in the same way?	Yes*	96	51.6
	No	55	29.6
	Don't know	35	18.8
Do you think this type of cell division, for the production of sex cells, also occurs in plants?	Yes*	103	55.4
	No	83	44.6
Student's reasons**	No answer	145	78.0
	Correct answer	41	22.0

*Correct answer
** The reasons were written by students in a space that was available after each question to justify their choices.

Table 2 shows that 51.0% of the sample chose the correct answer (four chromosomes), and 23.2% chose wrong answers, while 25.8% indicated that that they didn't know the answer. This might indicate, apparently, that nearly half of students understand the concept, but this is not really the case, i.e. students do not really understand *cell division for growth and repair*. This conclusion is backed by students' written responses, where only 34.4 % of the sample students provided the correct reason. Most of the students wrote incorrect explanations for their choices. The correct reason for the right alternative (four chromosomes) is: "*because the division is direct, which occurs in somatic cells*". Following are examples of the 'translated' incorrect reasons provided by students:

- *Skin cells are divided into chromosomes fewer than half of the new cell.*
- *The original skin cells and the new skin cells contain different genetics*
- *The cells can grow, but can't divide.*

Regarding their answers to the question that asks about whether original skin cells and the new cells give the same or different genetic information, about 67.2% of the sample chose the correct answer "*the same*", and 16.1% of them gave wrong answers (different genetics), while 16.7% indicated that they do not know the answer. This indicates that 32.8% of the students hold alternative conceptions about the concepts related to indirect cell division. These results might also indicate that most students understand the concept. But this is not really the case, because only 44.6% of the students were able to provide the correct reason for their correct choice. This means that most of the students in the sample do not clearly understand the concepts related to indirect cell division and genetic information transfer.

Concerning students’ answers to the question which asks if indirect division is the same for muscle, testis, egg, kidney, and stomach or not, Table 2 shows that the percentages of the sample students who were able to provide the correct answers are: 60.7% for the muscle, 56.5% for the kidney, 51.6% for the stomach, 38.2% for the testis, and 30.1% for the egg, and. These results show that students do not recognize that the same indirect division takes place in all types of cells. Regarding students' answers to the question which asked whether "this type of cell division, for the production of sex cells, also occurs in plant" 55.5% of the sample chose the correct answer "Yes". We concluded that students have difficulty in differentiating between direct and indirect division in the animal cells. They also have difficulties differentiating between the animal cells and plant cells. This conclusion can be clarified form students' reasons to their choices, where only 22% of the sample wrote the correct reason even for their correct choices and the rest did not write any reason.

The second part of the first question is related to students' understanding of cell division for the reproduction of sex cells. Table 3 includes the frequencies and the percentages of the students' answers to the items of the question, *“If the original cell contained three chromosomes, what chromosomes do you think the egg cell would contain? Why?”*

Table 3
Result of students’ understanding of cell division for the reproduction of sex cells (Question 1 part2)

Question	Answer alternative	n	%
During the sex cells' division, what is the number of chromosomes in the new egg cell?	Twice the original number	28	15.1
	The original number	31	16.7
	Half the original number*	96	51.6
	Don't know	31	16.7
Students reasons**	No answer	119	64.0
	Correct answer	67	36.0.
Would the new egg cell contain the same or different genetic information?	The same information*	103	55.3
	Different	41	22.1
	Don't know	42	22.6
Students reasons**	No answer	124	66.7
	Correct answer	62	33.3
Would the muscle cells divide in the same way?	Yes	36	19.4
	No*	150	80.6
Would the testis cells divide in the same way?	Yes*	114	61.3
	No	72	38.7
Would the ovary cells divide in the same way?	Yes*	107	30.1
	No	79	57.5
Would the kidney cells divide in the same way?	Yes	22	11.8
	No*	164	88.2
Would the stomach cells di-	Yes	16	8.6

vide in the same way?	No*	170	91.4
Would the skin cells divide in the same way?	Yes	35	18.8
	No*	151	81.2
Would the plant cells divide in the same way?	Yes*	95	51.1
	No	91	48.9
Student's reasons**	No answer	141	75.8
	Correct answer	45	24.2

*Correct answer
** The reasons were written by students in a space that was available after each question to justify their choices.

From Table 3, we can deduce that students hold alternative conceptions about the concepts related to *cell division for the reproduction of sex cells*. For example, they believe that the number of the sex cells will be reduced to half of the original number. Even though 51.6% of the sample students chose the correct alternative, only 36% of the sample gave the correct reason for their choice. This indicates that they do not understand the concepts related to sex cells' division.

Regarding students' responses to the question, "*Would the egg cell contain the same number of information chromosomes found in the original cell?*" the correct response was given by 55.3% of them, but only 33.3% of the sample were able to write the correct reason. This means that they do not understand the concepts related to egg cells' division.

The analysis of students' answers to the question, "*Is the indirect division the same for muscle, kidney, sperm, and egg?*" are presented in Table 3, which shows that the percentage of the sample students who were able to provide the correct answers is 91.4% for the stomach, 88.2% for the kidney, 81.2% for the skin, 80.6% for the muscle, 61.3% for the testis, and 30.1% for the ovary. It means also that students have difficulty differentiating between direct and indirect division in the animal cell; they also think that the reduction division takes place only in the sex cells. Students' answers to the last sub-question in Table3 indicate that they do not understand the both sexual and asexual cell division. Although 51.1% of them choose the right answer, only 24.2% of the sample provided the correct reason for their choices. Following are examples of the alternative conceptions held by students about cell division for the reproduction of sex cells:

- *The number of chromosomes in the new egg cell is twice or equal to the number of chromosomes in the original egg cell.*
- *New egg cell contains different genetic information.*
- *Plant cells do not divide in the same way as the animal cells do.*

The second question of the study was related to the nature of students' understanding of asexual and sexual reproduction in animals and plants. This question includes three parts. The results of students' responses to this question are presented in Table 4.

Table 4
Frequencies and percentages of students' understanding of asexual and sexual reproduction in animals and plants

Question	Answer alternatives	N	%
Draw a diagram, an egg containing 3 chromosomes	No or incorrect diagram	98	52.7
	Completely or partially correct diagram	88	47.3
How many chromosomes will be found in the SPERM cell?	6 chromosomes	31	16.7
	5 chromosomes	3	1.6
	3 chromosomes*	88	47.3
	2 chromosomes	24	12.9
	Don't know	40	21.5
Students' reasons**	No answer	129	69.4
	Correct answer	57	30.6
What is the number of chromosomes that would be found in the new fertilized cell?	6 chromosomes*	74	39.8
	5 chromosomes	6	3.2
	3 chromosomes	28	15.1
	2 chromosomes	21	11.3
	Don't know	57	30.6
Students reasons**	No answer	130	69.9
	Correct reasoning	56	30.1
Why do you think an animal that could reproduce asexually would still need to reproduce sexually?	No idea	116	62.3
	Have some idea	70	37.6
I think that………**	No answer	180	96.8
	Correct reasoning	6	3.2
How you think plants reproduce?	Sexual reproduction	19	9.6
	Asexual reproduction	39	21.1
	Both*	102	54.8
	Don't know	27	14.5
Students' explanation**	No answer	139	74.7
	Correct reasoning	47	25.3

*Correct answer
** The reasons were written by students in a space that was available after each question to justify their choices.

The data of the first part of the question (Table 4) show that only 47.3% of the students were nearly able to draw the right diagram of the cell, this indicates that they partially understand the egg cell. But, when analyzing their drawings, we found that they lacked the basic drawing skills. In addition, students did not clearly write the required data on their drawing. The majority of the students misunderstood the concepts related to cell structure, which is required for the understanding of genetics concepts. Figure (1) shows a sample of students' drawings of an egg cell.

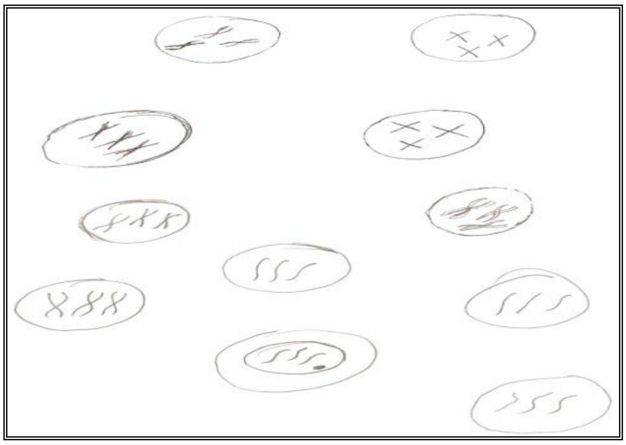

Figure 1. Sample of students' drawings of the egg cell.

When asked about the number of chromosomes in the sperm (Question 2, part 2), students gave a variety of responses, but only 47.3% of them chose the correct answer: "*three chromosomes*". This indicates that they do not understand the basic concept of heredity and genetics, especially the difference between reduction division and normal division. Regarding the reasons for students' choices, only 57 students (30.6%) wrote the right reason. The rest of the sample left the provided spaces empty. This indicates that the majority of the students lack the scientific understanding of asexual and sexual reproduction in animals and plants.

For the students' response to the question, "What will be the number of chromosomes in the new fertilized cell?" only 39.8% of the students chose the correct alternative - six chromosomes. Regarding students' explanations for their answer to this part, only 56 students (30.1%) wrote the correct reason. The rest of the sample wrote wrong explanations, such as "*because they occur in the animal cells*". This result is another indication that the majority of the students lack the scientific understanding of asexual and sexual reproduction.

Concerning question4, it was found that most of the students (62%) have no idea about the reason behind an animals' ability to reproduce asexually, and would also need to reproduce sexually. Almost all students (96.8%) also did not write any reason for their responses. This would indicate that they do not understand the concepts related to sexual and asexual reproduction.

Regarding the students' response to the question related to the type of reproduction in plants, 54.8% of them chose the correct alternative, which is sexual and asexual reproduction. The rest of the students chose incorrect alternatives, and only 25.3% of them were able to give the correct interpretation for their choice, which indicates that they do not know how reproduction in plants occurs.

Table 5 includes frequencies and percentages of students' understanding of genetic information transfer.

Table 5
Frequencies and percentages of students' understanding of genetic information transfer

Question	Answer alternatives	n	%

If you could take two of Saeed's cheek cells, would the genetic information be:	The same* Different Don't know	106 28 52	57.0 15.0 28.0
Students' reason**	Correct answer No answer	72 114	38.7 61.3
If you could take one of Saeed's cheek cells, and one of his nerve cells would the genetic information be:	The same* Different Don't know	41 85 60	22.0 45.7 32.3
Students' reason**	Correct answer No answer	50 136	26.9 73.1
If you could take one of Saeed's cheek cells, and one of his sperm cells would the genetic information be:	The same Different* Don't know	58 59 69	31.2 31.7 37.1
Students' reason**	Correct answer No answer	58 128	31.2 68.8
If you could take two of Saeed's sperm cells, would the genetic information be:	The same* Different Don't know	83 41 62	44.6 22.1 33.3
Students' reason**	Correct answer No answer	48 138	25.8 74.2

*Correct answer
** The reasons were written by students in a space that was available after each question to justify their choices.

Table 5 shows that 57% of the sample chose the correct alternative for the first question, but only 38.7% were able to provide the correct reason for their choice. The results for the second question indicates that only 22% of the students chose the correct answer " the same", while 45.7% chose the wrong answer " different" and 32.3% indicated that they do not know the answer. The percentage of students, who reasoned correctly, was 26.9, which is slightly higher than those who chose the correct answer. This results show that students have alternative conception "the genetics information of the cheek cells, and the nerve cells are different"

Similarly, the results for the third question shows that only 31.7% of the students chose the correct answer "different ", while 31.2% chose the wrong answer " the same " and 37.1% indicated that they do not know the answer. The percentage of students, who reasoned correctly, was 31.2%, which is nearly the same as those who chose the correct answer. This results show that students have alternative conception "the genetics information of the cheek cells, and the sperm cells are different"

Table 5 also shows that 44.6% of the sample chose the correct alternative for the fourth question, but only 25.8% were able to provide the correct reason for their choice. Regarding the second, third, and the fourth questions, which are related to genetic information transfer, the percentage of those who chose the correct answer or gave the correct reason is low, which means that students have partial or complete misunderstanding of the genetic information concepts. Students hold an alternative conception, that "the sperm cells' genetic information is not the same. As a result, we concluded that students hold the following alternative conceptions:

- *They think that somatic cells of the same type (for example, cheek cells) have different information.*
- *They also think that somatic cells of different types (for example, a cheek cell and a nerve cell) have different information.*
- *Students believe that one somatic cell and one germ cell (a cheek cell and a sperm cell) have different information.*
- *Students also believe that two germ cells (sperm cells) have different information.*

Discussion

Previous research has examined students conceptions of genetics and reproduction (Lewis and Wood-Robinson, 2000; Lewis, Leach & Wood-Robinson, 2000a; Lewis, Leach & Robinson, 2000b; Chattopadhyay, 2005), and most of these studies show that students hold substantial alternative conceptions of such biological concepts. This paper discusses the alternative conceptions held by secondary school student (11th graders) in concepts related to genetics and heredity.

The results of this study show that students hold many alternative conceptions related to the following: indirect cell division, sexual reproduction, asexual reproduction, and genetic information transfer. They have difficulty in differentiating between asexual and sexual reproduction, and there is an overlap in students' understanding of the mechanisms of transferring heredity and genetics' characteristics in reproduction and cell division. The results of this study also show similar types of misconception to those found in Lewis et al (2000c), which persist even at higher levels of schooling. The study also revealed that the majority of students are unaware of the nature of genetic information present in different types of cells within the same individual, and none could distinguish between somatic and germ cells. These types of alternative conceptions have weakened students' ability to explain their answers on the questionnaire. This conclusion is backed by students' incorrect reasons to explain most of their choices, even the correct ones, which indicates that students lack the ability to explain their choices, even when they are correct. Most of these results are consistent with results found among Indian high school students Chattopadhyay (2005), and students in the UK (Lewis and Wood-Robinson, 2000). Examples of student alternative conceptions are:

Alternative conceptions about direct and indirect cell divisions:

- *Skin cells are divided into chromosomes fewer than half of the new cell.*
- *The original skin cells and the new skin cells contain different genetics*
- *The cells can grow, but can't divide.*

Alternative conceptions about reduction division for the reproduction of sex cells:

- *The number of chromosomes in the new egg cell is twice or equal to the number of chromosomes in the original egg cell.*
- *New egg cell contains different genetic information.*
- *Plant cells do not divide in the same way as the animal cells do.*

Alternative conception about Genetics information transfer:

- *They think that somatic cells of the same type (for example, cheek cells) have different information.*
- *They also think that somatic cells of different types (for example, a cheek cell and a nerve cell) have different information.*
- *Students believe that One somatic cell and one germ cell (a cheek cell and a sperm cell) have different information*
- *Students also believe that two germ cells (sperm cells) have different information.*

Chattopadhyay (2005) argued that the gap between classical and molecular genetics remains an obstacle to the development of a holistic concept of genetics because they are taught at different levels which often are not connected properly. The inclusion of the basic conceptual framework for understanding the concepts related to hereditary information and the basic mechanisms involved in the evolution of living beings (Chattopadhyay, 2005; Banet and Ayuso, 2003; Lewis et al 2000c) would help students to understand the biological significance of certain phenomena such as cell division and reproduction. It would also help students' understanding of genetic relationships, which is the main obstacle to building a 'coherent conceptual framework'. Teachers, when teaching genetics and inheritance, should identify related ideas and draw them together so that students can develop further understanding of genetics and inheritance. Similarly, we could argue that it is important to look at our biology curriculum to see if there are any gaps in the presentations and organizations of the concepts, and if the basic conceptual framework for understanding the concepts related to genetics is included properly.

Why do students encounter difficulty understanding such concepts? How could we explain our results from the educational point of view? Constructivists indicated that abstract concepts such as genetics related concepts are hard to learn. Students need to have high operational abilities in order to understand abstract concepts (Piaget, 1964; Piaget, 1952; Piaget, 1971). Constructionists also argued that the inability to represent abstract ideas in concrete and malleable forms or make abstract concepts more accessible and more readily internalized as mental schema may cause misconception and alternative conceptions. They stressed that the ability to represent abstract concepts such as genetics, may ensure meaningful learning because meaningful learning would enable students to comprehend and then be able to apply knowledge in their future life. Literature (Stepans, 2003; Demirci, 2003) indicated that there are many factors affecting students' abilities, especially the ability to understand concepts, especially abstract concepts such as cell division, reduction division, and reproduction. These factors are:

- Lack of the ability to perform formal operations, which is necessary to deal with abstract concepts.
- Language used by the teachers and textbooks.
- Conflict between students' everyday experience and the classroom.
- Confronting students with abstract concepts at an early age.

- Giving students information that is not relevant to their lives or related to their surrounding environment.
- Using traditional teaching methods such as lecturing, which fail to deal with students' alternative conceptions.
- Socio-religious factors may affect students' understanding of controversial concepts such as genes and heredity.

Conclusions

To make real change in students' learning, especially of abstract concepts such as indirect cell division, reduction cell division, reproduction and genetic transfer, we must consider these factors, whether in designing biology and science textbooks, or in teaching biology and science concepts. Teachers should use teaching methods and strategies which ensure the real participation of students in the learning process. Students should be active learners rather than passive recipients of information. In addition, experts and science curriculum developers should include real-life activities that allow students to build their scientific knowledge for themselves.

From the nature of students' responses to the questions one can deduce that they have a poor understanding of genetics concepts, such as indirect cell division, sexual and asexual cell division, and genetic information transfer, which are important to their future personal and academic life. This type of understanding might result from the nature of the science curriculum, or from the teacher's background. Therefore, we suggest the following:

- The biology text books for secondary schools in particular, and science text books in general, should be revised and developed in such a way as to be able to deal with misconceptions.
- The biology and science teacher preparation programs should concentrate on alternative conceptions held by students and provide teachers with appropriate skills to deal with biology and science misconceptions.
- The curriculum should provide opportunities for students and teachers to use and develop such knowledge and skills through a consideration of scientific literacy and contemporary issues related to students' real life and to their society, set within a range of science contexts.
- A study to investigate the sources of Saudi Arabian secondary students' alternative conceptions of controversial issues is needed.

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