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Misconceptions of Primary and High School Students Related to the Biological Concept of Human Reproduction, Cell Life Cycle and Molecular Basis of Heredity

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ABSTRACT

The aim of this research was to determine the misconceptions of students related to the concept of human reproduction. The research was conducted in the period from 2008 to 2012 in 41 primary and 36 high schools in Croatia, with a total sample of 1931 students. The analysis of the students' answers shows the scope and permanency of misconceptions and problems in the process of understanding the concepts related to human reproduction. The misconceptions associated with mitosis and meiosis, as well as human reproduction itself are particularly emphasised. The results show that students do not understand the purpose of mitosis and meiosis, what sex cells are and what their purpose is. A major problem for all students of both genders is the concept of ovulation and the menstrual cycle in general. The results indicate that the approach to teaching certain concepts should be changed, and that teaching content should be more appropriately distributed and better adapted to the students' developmental levels and interests. Future research should be focused on a more detailed analysis of the identified misconceptions in all grades

Keywords: human reproduction, meiosis, menstrual cycle, misconceptions, ovulation.

INTRODUCTION

Students' misconceptions in science classes imply a lack of understanding of fundamental scientific concepts and facts (Mestre, 2001). Science misconceptions are very resistant to change, especially when the traditional lecturing method is used (Eisen and Stavy, 1992; Bahar, 2003; Cimer, 2007; Hakim et al., 2016). It has been observed that misconceptions acquired more recently could be eliminated easily, while those acquired at very early ages remain entrenched and impervious to change (Griffiths and Moon, 2000; Pace Marshall, 2006). Preconceptions could also pose strong barriers to understanding science, as they might also act as misconceptions (i.e., they might interfere with scientific concepts) and could be difficult to foresee and therefore to control (Fetherstonhaugh and Treagust, 1992; Evans and Winsløw, 2007). To be able to change this kind of situation, it is necessary to

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identify students' misconceptions prior to teaching and to identify those misconceptions that hinder learning (DiSessa, 2002; Chi, 2005).

The study of misconceptions was begun almost thirty years ago by Rosalind Driver (Driver, 1988; Driver and Easley, 1978) in a series of studies on students' understanding of key concepts in many scientific disciplines. Smith and Anderson (1984) pointed out that in teacher education programs, the attention of prospective teachers should be focused on the effects misconceptions might have on learning, and on developing ideas for introducing conceptual changes in the learning process. Hence, besides the necessary theoretical knowledge, teachers also need to develop profound observation skills to effectively meet the students' needs and interests (Smith and Anderson, 1984; Kurt et. al., 2013). Teachers should also be able to recognize common student misconceptions, develop skills to diagnose the misconceptions and adopt specific strategies for overcoming them, as well as to adapt curriculum materials to already identified student preconceptions. However, it is very difficult to explain the cognitive structures that emerge in an individual's minds after the process of learning (Kurt et. al., 2013).

The most often tested concepts in biology education research are associated with photosynthesis, genetics, evolution, and circulatory system. Within these conceptual frameworks, many misconceptions have been identified. A vast amount of published literature deals with misconceptions related to reproduction - one of the basic biological concept of living organisms - and its genetic-parental background and outcomes (e.g., Lewis et al., 2000; Emre and Bahsi, 2006; Akyurek and Afacan, 2012; Aydin and Balim, 2013). The most studied misconceptions about reproduction are related to cell division and many studies discuss the problems and misconceptions related to mitosis and meiosis (Robinson and Lewis, 2000; Tekkaya et al., 2000; Atilboz, 2004; Brown, 2010; Dikmen 2010). Furthermore, Oztas et al. (2003) point out that both teachers and students consider the concept of cell division difficult and problematic, while simultaneously being aware that it is crucial for understanding a number of other biological concepts, including reproduction as a whole.

The finding that pre-service biology teachers have an incomplete insight into the students' understanding of the concept of reproduction is highly important and needs to be addressed. Some studies suggest that there is a problem with the conceptual understanding of reproduction across all academic levels. Thus, teachers could transmit their cognitive insufficiencies to their students, which could further result in incorrect learning (Kurt et. al., 2013); at the same time, adolescents bring into the classroom a number of preconceptions and misconceptions related to the topic of human reproduction, which often rely on poor basics of human reproductive physiology (e.g. Donati et al. 2000; Sydsjö et al. 2006).

Aim

The intention of this research was to: 1) identify the misconceptions of primary and high school students (14-19-year-olds) related to the concept of human reproduction and 2) determine their permanency. The study methodology involved participants completing tests/questionnaires on human reproduction topics that match the participants' age/grade. The permanency of the misconceptions was assessed through the employment of retention questions, which could point to critical points in the teaching and acquisition of certain concepts. Based on the research objectives, the following assumptions have been derived: 1) if specific problems with understanding the concepts of human reproduction occur in all groups of students with respect to the overall students' performance expressed by the percentage of test results, we can probably speak of the existence of misconceptions and 2) if the same misconceptions occur among students of different age groups, we can talk about their permanency and insufficient acquisition, or about a wrongly taught concept.

METHODOLOGY

The research was conducted as part of the project Student Competences in Teaching Science and Biology (MSES, 119-0091361-1223) in the period from 2008 to 2012. Schools from different settings, from small rural to larger town schools all over Croatia were included in the project, with the participation of 1035 students (41 primary and 36 high schools). Two on-line systems for checking the acquisition of basic biological concepts among students were used: Ampyx (www.ampyx.org) and MoD Moodle modification (http://mod.srce.hr/), with the questions compiled by teachers. For the purpose of this paper, only questions related to the concept of reproduction were taken from the database and analysed. Students from the eighth-grade in Primary and the first, second, third and fourth grades in High school (Table 1) were tested at the beginning and end of the school year. They answered 18 questions matching the teaching material of the currently attended grade and 6 questions from the previous grade. Hence, some of the questions (retention questions) were answered by students of two grades (two generations).

Table 1. *Sample of student age groups by grade and age*

PRIMARY SCHOOL	8th grade	HIGH SCHOOL	1st grade	2nd grade	3rd grade	4th grade
Student's age	14-15	Student's age	15-16	16-17	17-18	18-19

Using the $\chi 2$ test for analysing a total of 108 questions in all tested grades, those with poorer results were selected. A histogram of the correlation of students' overall performance and the answers to individual questions is used to analyse the relationship and meaning of the selected answers in detail, where the correct answer is positioned first in the diagram. Assuming that the frequency of choosing the correct answer by classes of overall student performance shows no statistically significant differences between individual classes of students, we expected that deviations in some results would indicate the existence of eventual misconceptions. If any of the distractors appeared equally in all classes of students, we assumed that a misconception exists. Ten classes were defined on the basis of decile values (Table 2) and the percentage of the students' test results for each grade. The lowest percentage was established as class I and students with the highest percentage of success were classified in class X (Figure 1).

Table 2. *Classification of students into success classes in decili by the overall performance for individual age groups*

Grades decili	8th PS	1st HS	2nd HS	3rd HS	4th HS
	Test results performance (%)				
10	29.17	29.17	26.92	26.92	22.86
20	33.33	33.33	32.00	31.43	25.71
30	37.50	37.50	36.00	36.00	31.43
40	41.67	41.67	40.00	40.00	31.43
50	45.83	45.83	43.74	43.74	34.29
60	50.00	50.00	46.15	46.15	37.14
70	54.17	53.85	48.15	49.08	40.00
80	58.33	58.33	52.00	52.17	51.43
90	66.67	66.67	59.26	59.26	57.14

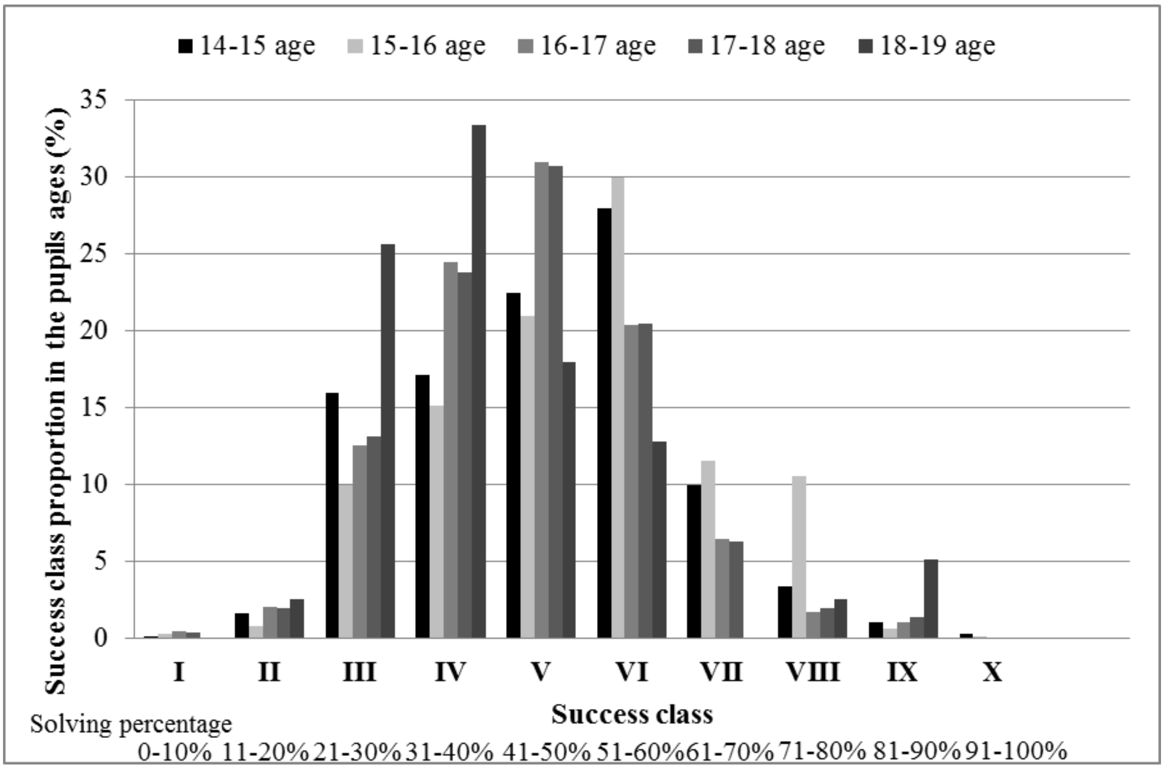

Figure 1. *Success classes based on solving percentage according to grades*

The 38 analysed questions related to the concept of reproduction from different fields are differently represented in this research; 7 matching questions were selected for the purpose of identification of misconceptions on the concept of human reproduction.

FINDINGS

The selected questions related to human reproduction are shown below according to the concepts they test (Table 3). The frequency analysis of the answers by overall performance showed statistically significant differences (χ^2 test, $P < 0.05$) between individual student results in 4 questions (V8T23, R8D12, V1D35, V1P27). In 3 cases (V8T22, R3D33, V4D34), the χ^2 test did not show significant differences in students' success, and the results indicated the existence of possible misconceptions (Table 3). Regarding the mean number of correct answers, there were no statistically significant differences between the differing age groups (χ^2 test, $0.09 < P < 0.90$) and genders (χ^2 test, $0.17 < P < 0.82$) (Table 3).

Table 3. *Selected questions for which students of different grades achieved weaker results and differences in the mean values for student age groups and gender according to the χ2 test*

	Question													
	V8T23		**R8D12**		**V8T22**		**V1D35**		**V1P27**		**R34D33**		**V4D34**	
N	285		393		259		214		217		161		101	
M	0.067		0.239		0.131		0.229		0.673		0.385		0.463	
SD	0.250		0.427		0.338		0.421		0.470		0.488		0.508	
χ^2	**41.095**		**17.531**		**8.142**		**34.389**		**28.970**		**5.965**		**8.261**	
p	*0.00*		*0.01*		*0.32*		*0.00*		*0.00*		*0.54*		*0.14*	
Gender	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**	**m**	**f**
N	142	143	176	217	125	134	83	131	88	129	67	94	44	57
M	0.06	0.07	0.26	0.22	0.12	0.14	0.28	0.20	0.66	0.68	0.40	0.37	0.61	0.38
SD	0.245	0.256	0.441	0.416	0.326	0.350	0.450	0.400	0.477	0.467	0.494	0.486	0.502	0.500

χ^2	**0.049**		**0.862**		**0.269**		**1.780**		**0.127**		**0.155**		**1.889**	
p	*0.82*		*0.35*		*0.60*		*0.18*		*0.72*		*0.69*		*0.17*	
Grade	**8. P**	**1. H**	**8. P**	**1. H**	**8. P**	**1. H**	**1. H**	**2. H**	**1. H**	**2. H**	**3. H**	**4. H**	**3. H**	**4. H**
N	149	136	88	169	103	156	59	155	50	167	45	116	67	34
M	0.05	0.09	0.26	0.19	0.17	0.10	0.19	0.25	0.68	0.67	0.36	0.40	0.36	0.50
SD	0.212	0.285	0.442	0.393	0.382	0.304	0.393	0.432	0.471	0.471	0.484	0.491	0.483	0.508
χ^2	**1,945**		**4.236**		**2.835**		**0.835**		**0.015**		**0.230**		**0.472**	
p	*0.16*		*0.12*		*0.09*		*0.36*		*0.90*		*0.63*		*0,49*	

N – number of students, M- average acquisition values, SD - standard deviation, P - primary school, H - high school, f – female, m - male

A low performance of only 4.70% was achieved by eighth-graders for question **V8T23,** and it was marked as a difficult question */Meiosis is a division that produces sex cells in sexual glands. Sex cells are formed from the initial cell with double the number of chromosomes. At the end of meiosis, four sperm cells and one egg cell are produced. How many DNA molecules will all the chromosomes in human cells have (2n = 46) before the initial cell division in the ovary (testicle*)?/ Equally weak results were also recorded for the first-grade high school students (8.82%), despite the positive selective enrollment in high schools and the repetition of curriculum topics. The analysis of the chosen answers shows that the number of correct answers is extremely low and occurs in the best and worst classes of students. The highest percentage of correct students' answers (1.8%) was recorded in class II. In general, all classes had a very high percentage of students who didn't answer the question - the exception was the class of highly successful students (Figure 1).

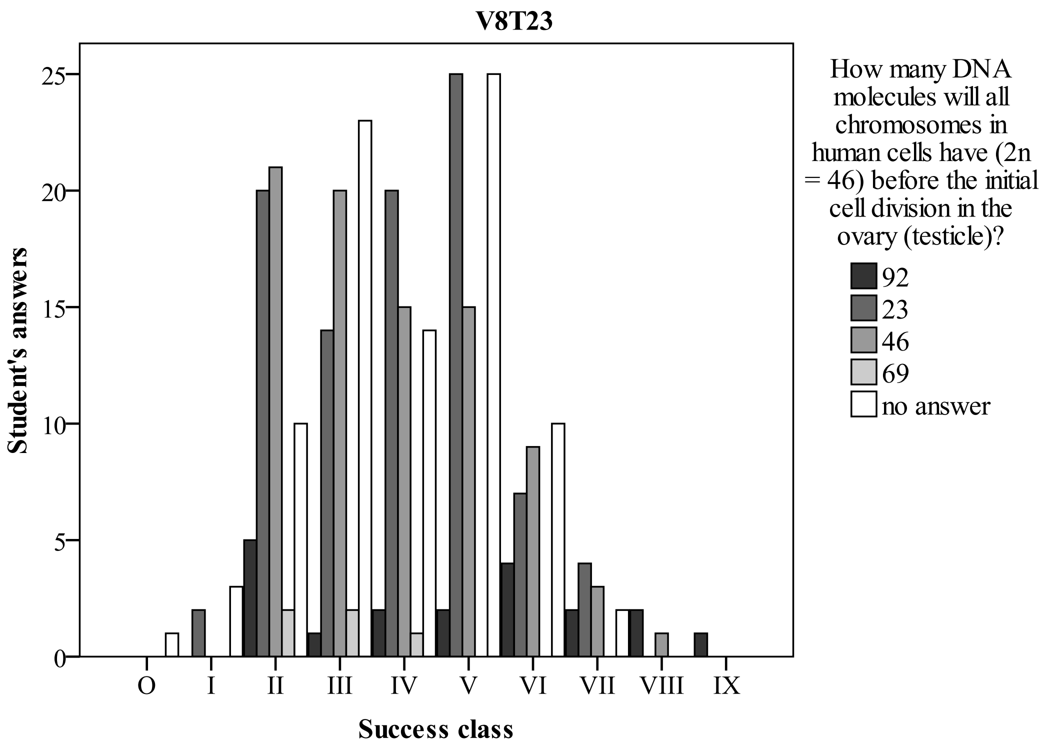

Figure 2. *Students' answers among differing success classes for question V8T23*

Question **R81D12** */Mark the correct statements about meiosis: a) Meiosis is a necessary precondition for the development of all living beings. b) Meiosis is essential for the growth and development of organisms. c) Meiosis allows sexual reproduction. d) Meiosis occurs in the sexual glands./* was correctly answered by 23.92% of students. Analysis of the chosen answers showed that the right answer did not prevail in any class of eighth-graders, but in all cases the significantly represented distractors were – *Meiosis is a necessary precondition for the development of all living beings* (36% of students) and *Meiosis is essential for growth and development of organisms* (16% of students). It is surprising that the first-grade high school students achieved better results by only 9.9% (Figure 2), although the current first-grade high school curriculum prescribes learning about DNA and the cell life cycle.

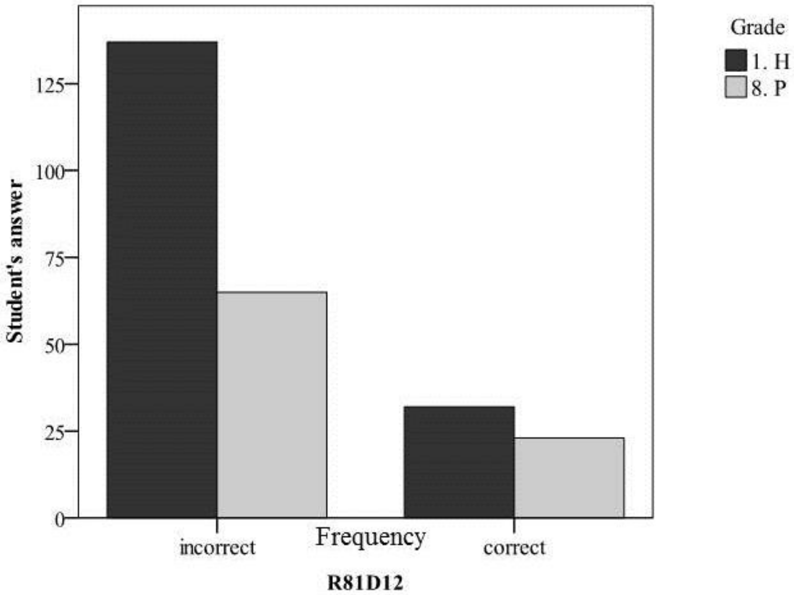

Figure 3. *Students' answers between the primary- (P) and high- (H) school grades for question R81D12*

Several questions about the *concept of human reproduction* from the curricula of different grades point to problems with understanding the concept of the menstrual cycle. Thus, the average result obtained for the more difficult question **V8T22** from the eighth-grade curriculum is 15.03% /*A woman whose menstrual cycle lasts 21 days had sex without using contraception on the* 12^{th} *day of the cycle. Assess the chances that fertilization occurred: a) very small because it has been five days since the ovulation b) high, because sexual intercourse took place only a day after ovulation, c) not particularly great, because the sexual intercourse did not occur on the day of ovulation, but on the next day, d) small, because ovulation occurs only on the* 14^{th} *day of the cycle*/. It has been noticed that older age groups achieved weaker results for this question (8.P = 52.9%, 1.H = 47.1%), although not statistically significant (Table 3). The analysis of the chosen answers showed that two distractors prevailed: *b) great, because sexual intercourse took place only a day after ovulation*, and *d) small, because ovulation occurs only on the* 14^{th} *day of the cycle* (Figure 3).

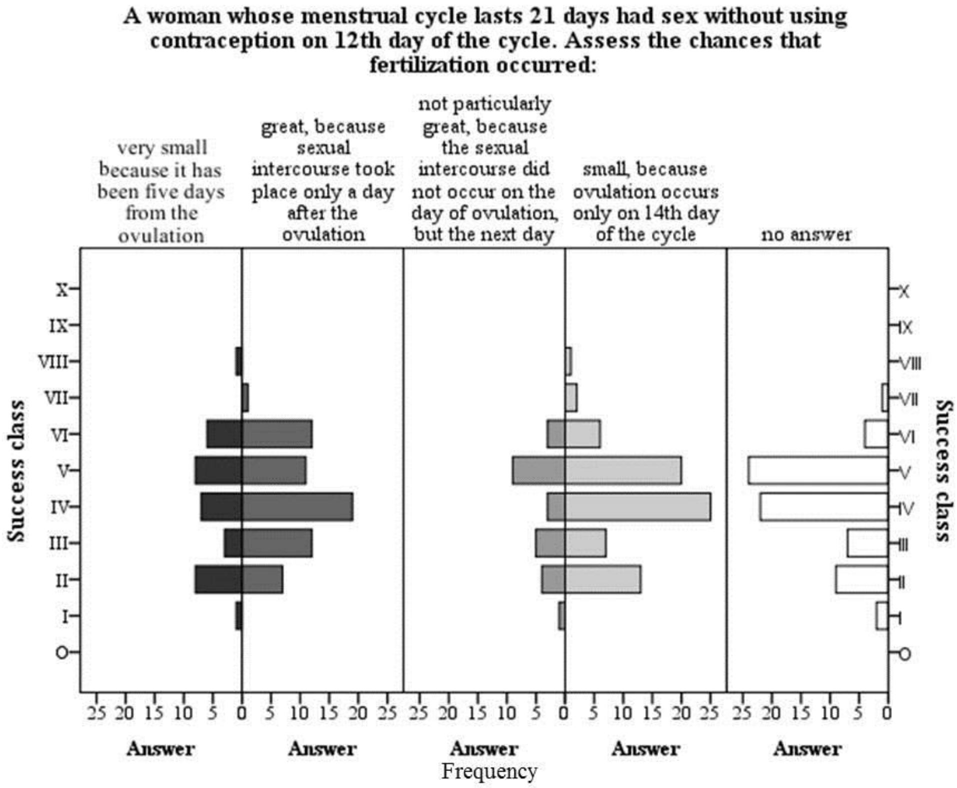

Figure 4. *Relationship between the answered questions and the success classes for question V8T22*

It turned out that students think ovulation always occurs on 14th day of the cycle or that it always occurs in the middle of the cycle regardless of its duration. From the frequency of the selected answers, and the statistically insignificant differences between the students' answers (Table 3), it can be concluded that these are very common misconceptions, but further research is needed due to the large number of students (26.1%) who did not answer the question at all. The analysis of the results revealed an equal distribution of answers in respondents of both genders (Figure 4), and the χ^2 test indicated that there was no statistically significant difference between the answers of male and female students (only 1.5% girls answered better). This result indicates the existence of identical problems and misconceptions as were observed for ovulation among students of both genders.

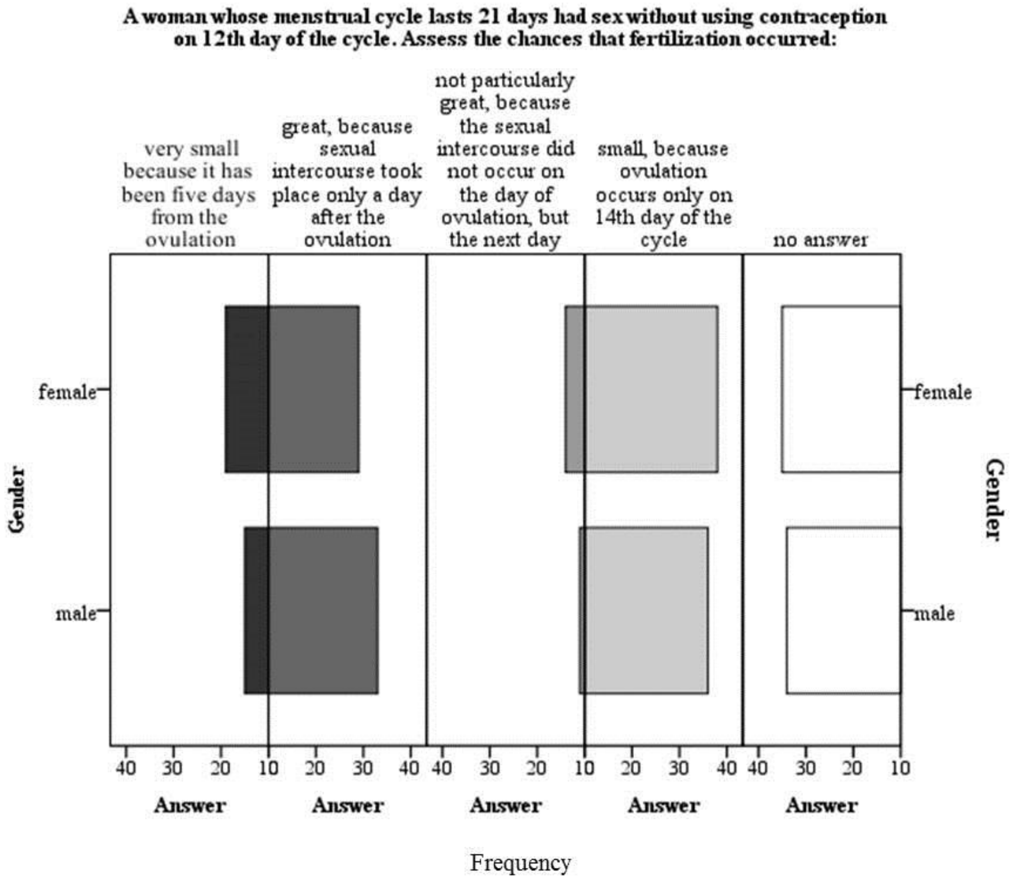

Figure 5. *Answers of female and male students to question V8T22*

Question **V1T35** */Which process does the figure show: a) oogenesis leading to the production of 1 egg cell, b) spermatogenesis leading to the production of 1 sperm, c) spermatogenesis leading to the production of 4 sperm cells, d) oogenesis leading to the production of 4 egg cells/* was correctly answered by only 22.17% of students. The analysis of the chosen answers showed that only students belonging to class X generally choose the correct answer, while all the others chose one of the distractors (Figure 5). Most students chose the distractor *oogenesis, four egg cells are produced* (40%) and the distractor *spermatogenesis, four seminal cells are produced* (32%). This result shows that students acquired a very poor basic knowledge of sex cell generation, although this topic is taught in the first high school grade.

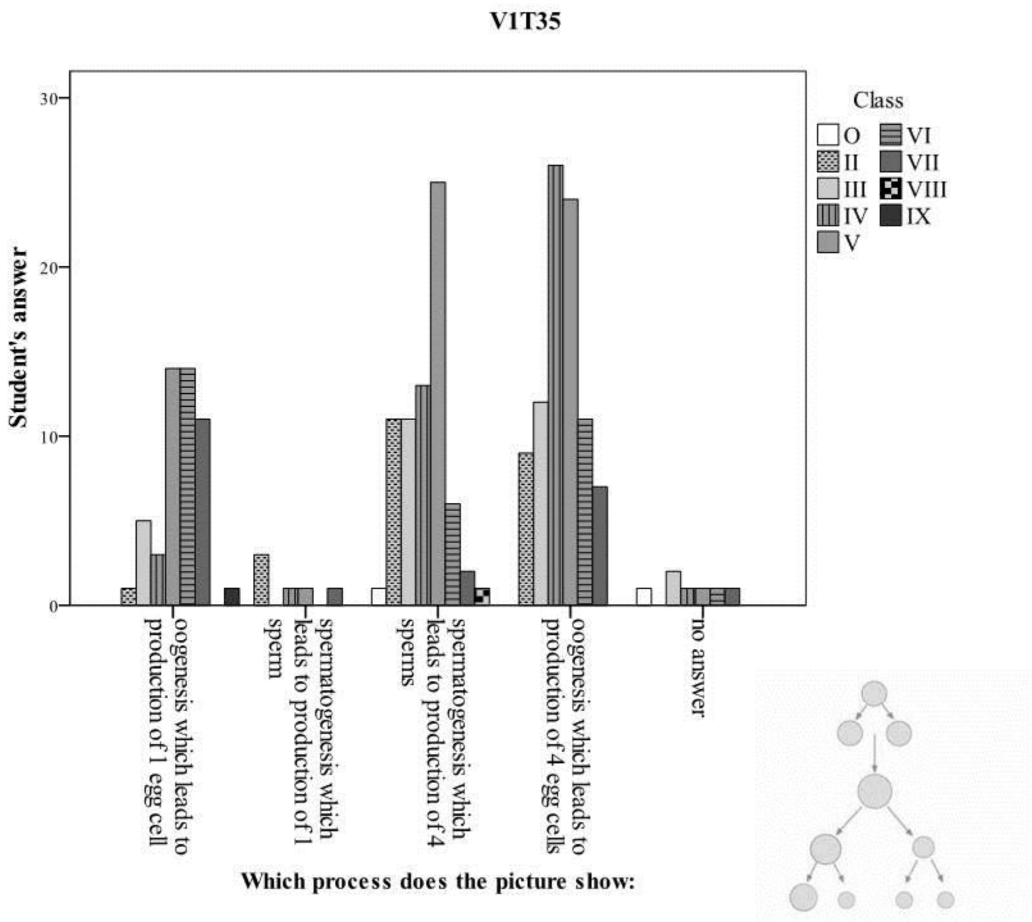

Figure 6. *Students' answers among the success classes for question V8T23*

The question **V1P27** for the first high school grade was selected */Without meiosis there would not be any: a) sex cells, b) reproduction, c) cloning, d) sexual dimorphism/* which was correctly answered by 67.3% of students. The equable result (1.H = 68%, 2.H = 67.1%) was achieved by students in both tested grades (Table 3). The analysis of the answers (Figure 6) showed a large number of correct answers (67.3%), but they decreased in proportion from the best class students (88.3%) to the weaker students (33.3%).

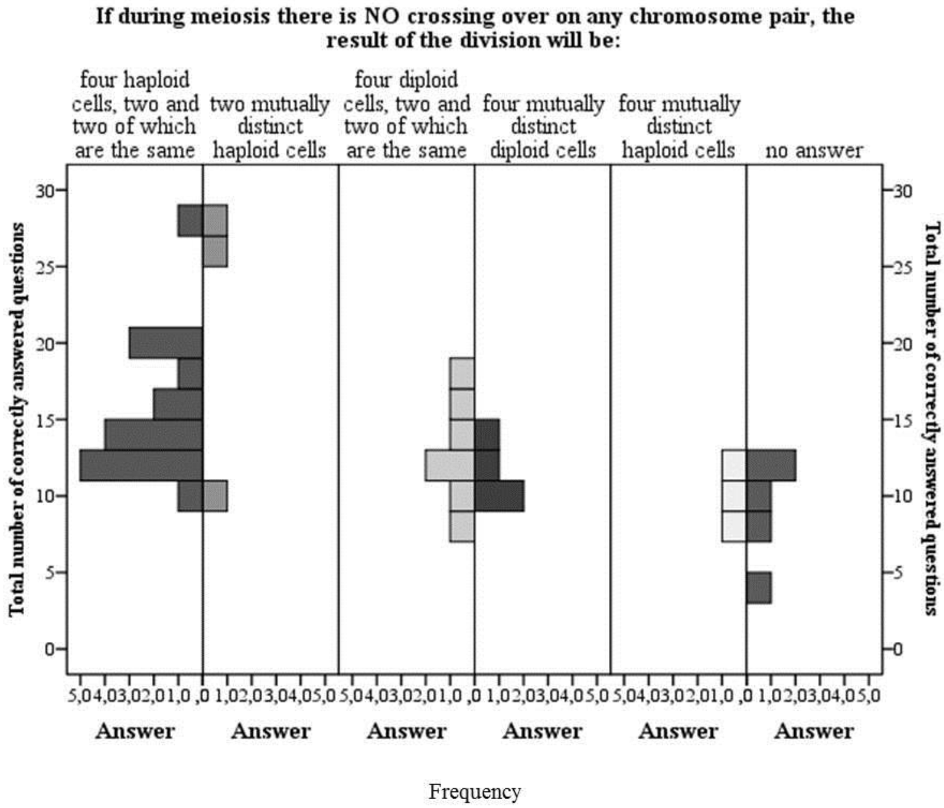

Figure 7. *Relationship between the answered questions and the success classes for question V1P27*

For question **R34D33** /*A young woman, whose menstrual cycle is regular and lasts for 33 days, got her regular period on 5 April. When is she most likely to be ovulating?/,* an average of 37.3% of third and fourth-grade high school students correctly specified the date of ovulation. The frequency analysis of the selected answers showed the largest number of correct answers in the success classes V and VI, and an equal number of wrong answers in classes I and VIII (Figure 7). The distractor -*22 April* was chosen by students of all classes, a total of 33%, and the distractor -*19 April* was most frequently chosen by students from class I, a total of 27%. This result confirms the existence of misconceptions about how to determine the date of ovulation, as already established in the previous question for eighth-grade students.

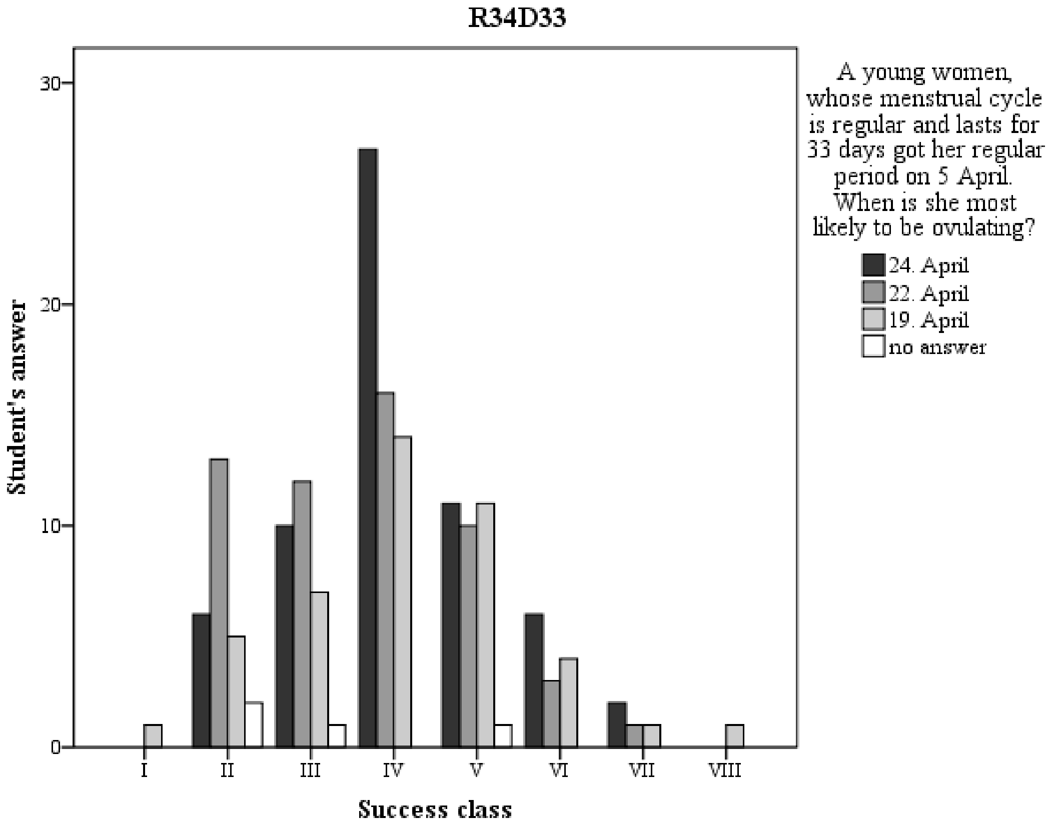

Figure 8. *Relationship between the answered questions and success classes for question R34D33*

A large number of students think that ovulation always occurs on the 14th day of the cycle or that it always occurs in the middle of the cycle, regardless of its duration. Similar to the previous question, the difference in the selection of answers by gender barely exists (Table 3). The overall performance is modest (39%), showing a slight upward trend in the older age group (Figure 8). The question is undoubtedly of vital importance and applicable in life, and therefore it is worrying that 26-28% of high school seniors think that ovulation occurs on 14th day from the beginning of the cycle. From the frequency of the selected answers, and the statistically insignificant differences between individual classes of students (Table 3), it can be concluded that these are very commonly expressed misconceptions in the population of students with less than 40% of total answer success. It means that more than a quarter of respondents have a misconception that could cause an unwanted pregnancy. Other respondents were divided almost equally between the correct answer and the distractor, which gives the middle date (*April 22*). Due to the structure of the question, it is not completely clear whether those who chose *22 April* just guessed, hoping that the correct answer was somewhere in the middle, or made a mistake in calculation. A mistake in the calculation was possible, given that the test was taken in a computer lab without a pen and paper, so many students counted by heart. This is an example of a well-conceived question that really tests the application of knowledge, but only limited conclusions can be drawn from its results: we know that a quarter of respondents have no expected knowledge and more than a third of respondents do. For a one third of the respondents, we can only say that they did not answer correctly and it is not known whether this is a result of ignorance or a calculation error.

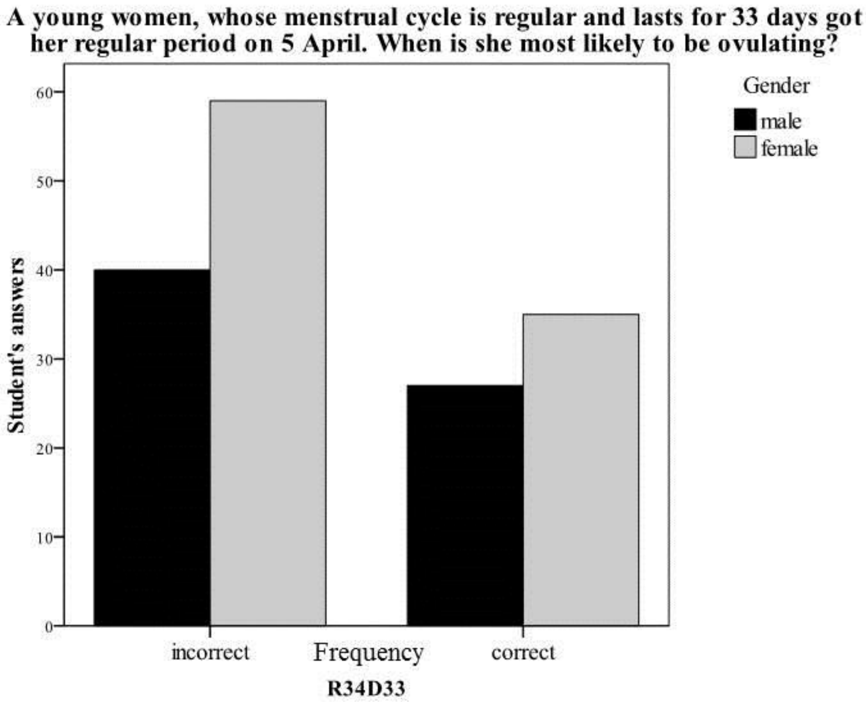

Figure 9. *Answers of third and fourth high school grade students to question R34D33*

The frequency of the selected answers in question V4D34 /*If during meiosis there is NO crossing over on any chromosome pair, the result of the division will be: a) four haploid cells, two and two of which are the same; b) two mutually distinct haploid cells; c) four diploid cells, two and two of which are the same; d) four mutually distinct diploid cells; e) four mutually distinct haploid cells/* showed that students chose correct and incorrect answers equally. Correct answers were recorded in all the success classes (Figure 9), while the highest percentage of incorrect answers (41.2%) was recorded in the first four success classes. While there were no significant differences between the students' answers (Table 3), it could be concluded that there are very commonly expressed misconceptions regarding haploid and diploid concepts during meiosis because 17.9% of students answered *four diploid cells, two and two of which are the same* (Figure 9) and 12.8% of students did not answer the question.

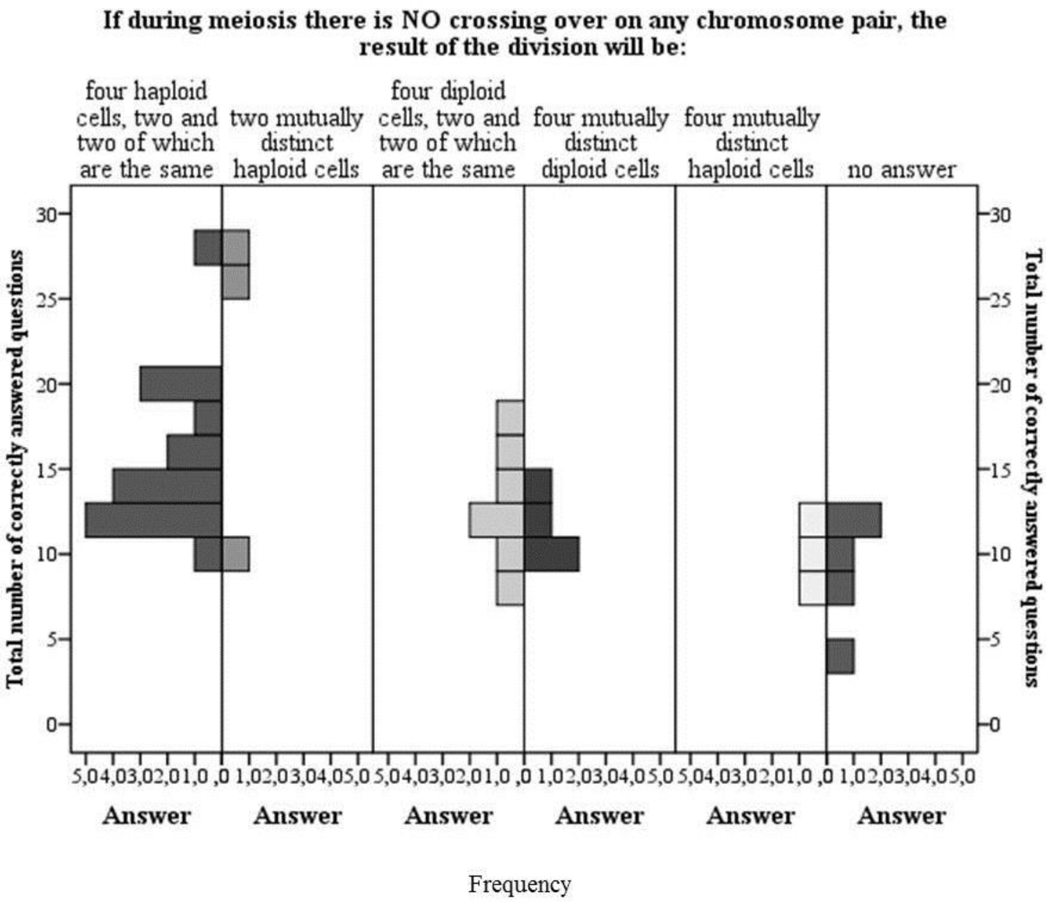

Figure 10. *Relationship between the total number of correctly answered questions and students' answer to question V4D34*

DISCUSSION

The present study supports the notion that primary and high school students have problems with the concept of cell division, especially understanding meiosis. As 36% of all students hold the opinion that meiosis *is essential for the creation of all living beings*, i.e. – *is essential for the growth and development of organisms*, it becomes clear that there is a problem in the conceptual understanding of crucial cell division events, although mitosis and meiosis are included in the curriculum for 14-year-old students. It turns out that some students have not acquired the concept of asexual reproduction, which does not imply meiosis, and other students obviously do not distinguish between mitosis and meiosis and their roles. Regarding the high prevalence of these distractors in all classes of students, we can talk about misunderstandings. It seems that the presentation of cell division in too much detail, as well as traditional teaching approaches, result in an overall misunderstanding of cell division processes.

Brown (2010) evidenced that the main learning problem among students of different ages in different countries is the lack of understanding of the meiosis aspects and their relationship to Mendelian genetics. Other biology education researchers have also described a number of problems with the understanding of meiotic division, especially processes related to chromosome number reduction (Robinson and Lewis, 2000; Tekkaya, 2002; Dikmenli 2010; Akyurek & Afacan, 2012; Aydin & Balim, 2013) and/or the role of nucleic acid (Flores et al., 2003). It has also been found that these misconceptions are remarkably resistant to change (Chi, 2005; Atilboz, 2004), though the research by Tekkaya (2002) showed (using the example of mitosis as well) that the best results in conceptual understanding and overcoming cell division misconceptions are achieved by a constructivist approach within teaching.

One of the basic concepts of living organisms is reproduction. The existing literature has identified various conceptions and misconceptions about: chromosomes, genes, meiotic and mitotic division, mutation, modification, DNA (Robinson & Lewis, 2000; Topçu & Şahin-Pekmez, 2009; Akyurek & Afacan, 2012; Aydin & Balim, 2013), genetic material and the connections between chromosomes, relationships between the behaviours of chromosomes during cell division (Lewis et al., 2000; Emre & Bahsi, 2006), diploid-haploid cells, the number of cells that emerge as a result of meiotic and mitotic division (Atilboz, 2004), distinctions among alleles, homologous chromosomes, replicated chromosomes, chromosome number and DNA (Tekkaya et al., 2000; Topçu & Şahin-Pekmez, 2009).

The analysis of the answers regarding the number of DNA molecules prior to initial cellular division in the ovary/testicles shows that the majority of 14- and 15-year old students have not successfully grasped the concept of the relationship between the DNA molecule and chromosomes. Some authors have demonstrated the existence of a misconception regarding the number of chromosomes in sex vs. body cells and a lack of understanding of the fact that different types of cells in the human body contain the same genes (Lewis et al., 2000; Robinson & Lewis, 2000; Topçu & Şahin-Pekmez, 2009; Aydin & Balim, 2013). A question related to this concept was used in Croatian national tests for 14-year-old students. The results showed that only 32.6% of the students gave the correct answers, and according to the choice of distractors, 26% of the students even showed a complete failure in understanding the concept (Radanović et al., 2011).

The analysis of the answers chosen by 18-year-old students (*If during meiosis crossing over* ***does not*** *happen on any chromosome pair, the result of the division will be…*) confirms that there is a significant proportion of students who fully or partially do not understand the process and result of *meiosis*. Many other authors evidence the same mitosis and meiosis conceptual understanding problems (Flores et al., 2003; Tamir and Zohar, 1993, Anderson et al., 2002; Hadjichambis et al., 2015). As the understanding of mitosis and meiosis is the foundation for understanding the processes and forms of reproduction, especially the genetics taught in the fourth high school grade, more attention should be paid to teaching these topics in the future. For more quality changes, further interventions in curricular planning, and the preparation and training of teachers would be needed. More attention should be given to problems concerning the basic mitosis and meiosis features and concepts, as the students might mix up the terms, especially after a time lag in learning. They are not sufficiently familiar with the root words used for the description of these cell divisions so they might have trouble permanently linking certain terms to the relevant meaning. If the terms are not continuously used and applied, they are subject to forgetting. Therefore, in teaching and student assessment, more attention should be paid to the descriptive determination of each division - especially when checking the retention of knowledge. Regarding the confusing mitosis and meiosis terminology issues, Akyurek and Afacan (2012) have found that eighth-grade students have developed alternative conceptions regarding the concepts of “chromosome”, “gene”, “meiotic division”, “mitotic division” and “DNA”. Robinson and Lewis (2000) carried out a similar study with 16-year-old students and found that they had an imperfect knowledge of “genes”, “chromosomes” and “cells”. We suggest that at the primary and secondary school level, memorising names should not be the real learning objective. Furthermore, if the curricular orientation inclines towards higher levels of cognitive skills and if the application of knowledge is highlighted, then curriculum success should not be measured on the basis of distinguishing names.

With regard to the concept of *Forms of reproduction*, the analysis of the answers to the question *Without meiosis there would not be ...* shows that almost a quarter of 15- and 16-

year-old students in all success classes show a complete misunderstanding of the role of meiosis in humans. This result could be compared to a very similar question for 14-year-old students, in which the misconception of meiosis as a *division that is necessary for the development of all living beings* was found. Besides the lack of conceptual understanding of meiosis, such answers also indicate the lack of differentiation between sexual and asexual reproduction in 14-16-year-olds. It seems that the perception of meiosis is still too demanding for 14-year-old students. The comparison of the results of all questions related to the concept of meiosis points to a very bad and worrying outcome of the overall teaching process. The situation is slightly better with 18-year-olds, although more than 40% of these students still have not acquired this concept. Other studies have evidenced similar results and the same misconceptions as the present study (Dikmenli 2010; Akyurek & Afacan, 2012; Aydin & Balim, 2013). It has been proven that these misconceptions are often resistant to elimination through conventional teaching strategies (Bahar, 2003). However, they could be corrected through the usage of inquiry-based learning techniques, as evidenced in the study of Hadjichambis et al. (2015), who conducted comprehensive research on over 6000 students. It is evident that problems with the concept of meiosis have been noted on a global level. Also, more comprehensive studies should be done along with teaching efforts to effectively resolve the problems with the students' acquisition of human reproduction topics and concepts.

Further in our analyses, it turned out that almost 80% of 15-year-old students have not acquired the concept of creating gametes and do not distinguish between *oogenesis* and *spermatogenesis.* The question taken from the curriculum taught to 14-year-old students reveals a very poor understanding of the concept of *ovulation* and the *menstrual cycle*. According to the analysis of the chosen distractors, the existence of two misconceptions can be noted. One is that *ovulation always occurs in the middle of the cycle*, and the other is that *ovulation always occurs on the fourteenth day of the cycle*. Thereby, the most frequent student misconceptions were used to create distractors (following the teachers' experience). Additional analysis of the selected answers by gender shows no significant differences in the choice of answers, indicating that established misconceptions exist equally in respondents of both genders. The same was observed for 17- and 18-year old students, and it further coincided with the research done by Yip (1998) that included 17-year-old students. Yip (1998) found that less than half of the candidates correctly identified the likely period of conception. A large number of students (40.5 %) thought that conception would most likely occur when the uterine lining was at its thickest. The poor performance on this issue indicated that many students do not understand the significance of the menstrual cycle in the reproductive process, although this is required in the Certificate level syllabus. The lack of understanding may be due to a variety of reasons, such as the tendency of students to learn by rote, or the use of ineffective teaching strategies (Yip, 1998). It is also interesting to compare these results with research on the knowledge of reproductive physiology and anatomy among adolescents in Sweden. Sydsjö et al. (2006) demonstrated that the level of knowledge tended to be higher in older age groups, and among the female population who responded correctly in 63.4% of cases vs. 21.4% of males. In our case, the proportion of answers shows no difference between males and females. However, a more thorough knowledge was expected for girls, as they often show significantly greater interest in the functionality of contraception than their male peer colleagues (Garašić, 2012). Although we expected some difference in the answers between boys and girls, it was not observed at all, so our results could be generalised and interpreted irrespective of gender. This could be emphasized as an important finding of our study. The analysed series of overall questions reveals that a large number of tested students aged 14-18 have problems with understanding content related to *human reproduction*, which is especially worrying because this knowledge is important for their daily life. It demonstrates that the facts and concepts considered basic knowledge among professionals in a subject are not broadly familiar and clear to the public in general. Our findings correlate with Hadjichambis et al. (2015), who stated that despite the importance of understanding how the human reproductive system works, adolescents worldwide exhibit weak conceptual understanding, which leads to serious risks, such as unwanted pregnancies.

CONCLUSION and IMPLICATIONS

The analysis of the students' answers to questions regarding the concept of *human reproduction* shows a large number of problems and misconceptions, and their retention among students of all ages. The results show that students do not understand the purpose of sex cells, mitosis and meiosis. Another major problem is observed in the misunderstanding of the ovulation and menstrual cycle shown by primary and high school students of both genders. Future research should be focused on the identified misconceptions, which should be analysed in more detail for all age groups and compared with the representation of related concepts in the curriculum. It would also be beneficial to identify an effective style of teaching for such complex concepts. Also, the increased use of active learning should be implemented, as it was suggested that this offers a significant contribution to conceptual understanding that might correct already acquired misconceptions. It is also important to examine the linguistic values of the terms for students and to determine how much students really understand the words and language structures that teachers use to explain the concepts.

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