Students' Misconceptions in Some Chemical Principles within a Biological Context

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Abstract

Science is all around us. From a young age, students start observing things around them and acquire knowledge from various sources such as, and including, the media and the social networks, which might not always be correct. At school, teachers try to keep scientific knowledge as simple as possible in order not to confuse and baffle students with content that they would not really need at that stage in their lives at school. However, at times, such methodologies might lead to incomplete or superficial knowledge that can eventually act as a hurdle or a barrier in the process of learning.
The aim of this research study was to provide an insight into students' misconceptions regarding some basic chemical concepts relevant to the topic "Part 2: Keeping Alive, Topic A: The Chemicals of Life", that is part of the 2014 Secondary Education Certificate (SEC) Biology syllabus (which leads to the 16+ examination at the end of Secondary school) in Maltese Secondary schools. The investigation dealt with eventual patterns present in any misconceptions in the four different groups involved in the study: girls and boys with Biology as their only Science subject, and girls and boys having both Chemistry and Biology as subject options at school.
The main research instrument used for this research study was a 30-minute multiple-choice test, taken by each of these four groups. The sample of students that were involved in the study was composed of about 20 students in each of the four categories. The outcomes of this research study suggest that, in general, students studying Chemistry harbour less misconceptions in certain chemical principles that are relevant to Biology. The study also shows that girls manifested less chemical misconceptions and that subject choice played a more significant role in the number of misconceptions for girls rather than for boys.

1. Introduction and Purpose of Study

Science is usually studied through the three main disciplines of Biology, Chemistry and Physics. Although these three disciplines focus on explaining the world we live in from different perspectives and approaches, the principles and concepts included therein can be highly interrelated. This relationship is very evident with certain chemical principles that serve as the foundation for the understanding and explanation of a number of biological concepts. In fact there is a whole branch of Science that specifically brings these two disciplines together, namely Biochemistry.
Chemistry is one of the fundamental branches of Science. Supposedly due to the fact that Chemistry is perceived as hard within the set of three Science subjects (Ozmen, 2004; Nakhleh, 1992) and as a lot of courses and possible fields of study only require a qualification in Biology as entry requirement, students might be tending to opt for the latter in conjunction with another subject, rather than with Chemistry. This phenomenon can be observed from analyzing the number of registered candidates for the Secondary Education Certificate (SEC) in the local scenario, in which there seems to be a decline in both the number of female and male students registering for the chemistry SEC exam between 2009 and 2015 (MATSEC statistical reports, 2009 to 2015).
If Chemistry is so important in understanding certain fundamental biological concepts, it is imperative that any misconceptions in these basic chemical principles should be on top of the priority list for educators. If these fundamental principles are not well and thoroughly understood in the first place, it will then be more difficult to continue building knowledge on faulty origins. This is even more important for students who intend to further their studies in the Science subjects in question. It is logical to conclude that students who study Chemistry with Biology might be advantaged in understanding the bigger picture behind certain biological principles.
However, since misconceptions can have multiple origins, students studying Chemistry might still encounter problems in thoroughly understanding and hence applying the most basic chemical principles. It can also be the case that students segregate and compartmentalise knowledge, and hence they do not manage to apply the concepts that they learn in Chemistry in a biological context.

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At times students may also interpret the same scientific concept (in this case a chemical one) in different ways according to the Science subject in question. This can result in a major source of misconceptions, where subject choice is not really a variable in the equation.

2. Methodology

The research tool consisted of a multiple-choice test that was to be given to four different groups consisting of twenty students each. These four groups, according to their option subjects, were: boys having Biology and Chemistry; boys having Biology only; girls having Biology and Chemistry; and girls having Biology only. In order to avoid another variable at play, Church schools were considered for the research.

Three different schools (one girls' and two boys' schools) satisfied the required criteria. Each school was then approached to inquire whether the given group of students would have covered "Part 2: Keeping alive, Topic A: The chemicals of life" (within the 2014 Secondary Education Certificate (SEC) Biology syllabus) by the time the multiple-choice test was to be administered. After the three participating schools had the relevant information sheets, consent forms and approval letters, the multiple-choice test was handed to every school. The researcher collected the completed tests after being contacted by the schools.

The multiple-choice test consisted of 12 questions. The time allotted was 30 minutes, which gives an average of two and a half minutes per question. Thus it was considered that respondents had ample time to tackle and answer the questions, and so time would not be a limiting factor. The test questions covered four main Chemistry topics that are relevant in SEC level Biology: States of matter (melting and dissolving), Concept of a chemical reaction, Chemical bonding (bond breaking and forming) and Catalysts(in relation to enzymes).

The type of data in this research is nominal/categorical, as all the data represents two main variables, namely gender and subject option. Since these variables are entirely separate categories, this is nominal or categorical data (Cohen et al., 2011). The results were portrayed graphically, where the percentages, rather than the actual frequencies, were used for the plots, so as to obtain a better comparison. Figure 1 in the results section depicts a general comparison of correct answers between Boys and Girls having Biology only vs. Boys and Girls having both Biology and Chemistry; whereas Figure 2 shows the correct responses of every question for the four different groups: Boys having biology only, Girls having biology, Boys having Biology and Chemistry and Girls having both Biology and Chemistry.

3. Results

From Figure 1 below, it can be concluded that, in general, students who had both Biology and Chemistry as subject choices, performed better in the multiple-choice test.

One notes that students with Biology (but not Chemistry) only managed to get a higher percentage of correct answers in three out of the twelve questions; these were questions 2, 4 and 7. Question 2 dealt with the concept of a physical and a chemical change. The most common response for both groups was option A (instead of the correct option B in the multiple choice test), where the difference between a physical and a chemical change was explained in terms of reversibility of the reaction: a physical change is reversible whilst a chemical change is not. This same observation was also cited by Nakhleh (1992). Questions 4 and 7 both dealt with the concepts of melting and dissolving. A total of 70.6% of the Biology only students correctly identified that during the process of dissolving, new intermolecular forces will be forming between the solute and the solvent, whereas only 39.1% of the Biology and Chemistry students opted for this correct answer. On the other hand, the majority of the students having both Biology and Chemistry (43.5%) opted for answer A (chemical bonds have to be broken, so that new ones can form). However it was only in question 4 that the Biology only students outperformed the Biology and Chemistry group by a significant percentage difference, at 39.5%. On the other hand, in questions 2 and 7, the percentage discrepancy in favour of the Biology only students was below 10% in both cases, at 7.8% and 9.2% respectively. Although in the majority of questions, students having both Biology and Chemistry obtained a higher percentage of correct answers, a significant divergence (taken at higher than 20%) was only registered in questions 3 and 9.

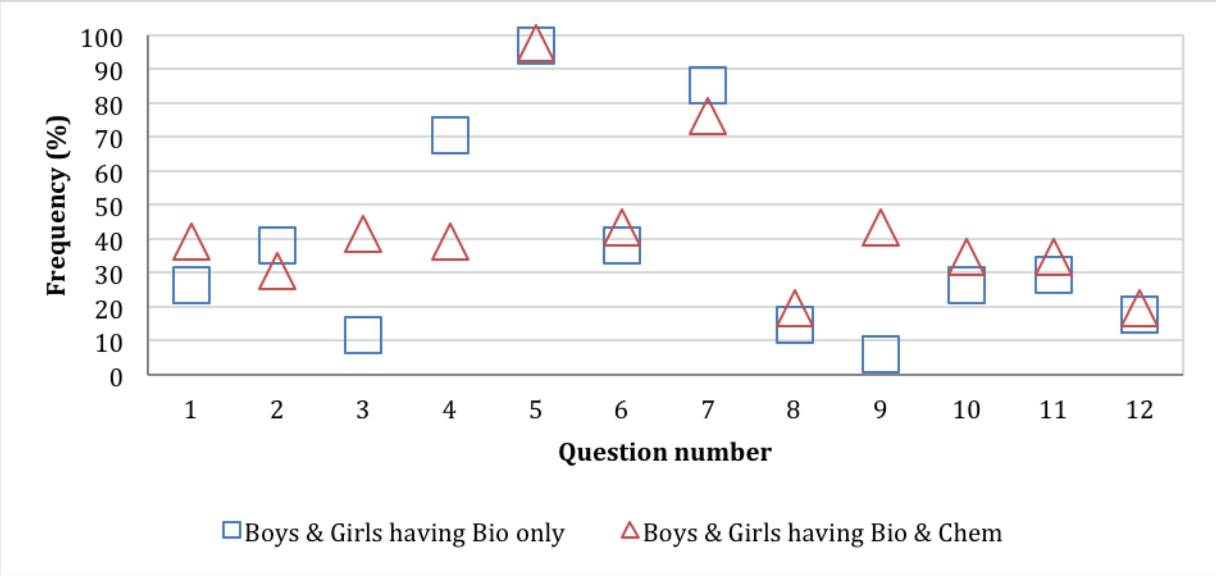

Fig. 1 Graph showing percentage frequency of correct answers per question, for the two groups

In question 3, where students were asked to identify which of the options given was not a chemical reaction, the Biology and Chemistry students fared better than the Biology only ones. The correct answer – B: the change in copper(II) sulphate crystals after the absorption of water vapour is not a chemical change – was chosen by 41.3 % of the Biology and Chemistry students. On the other hand, the correct option (B) was only chosen by 11.8% of the students having Biology only. This may be due to the fact that Chemistry students are at an advantage since the change in copper(II) sulphate crystals is discussed in Chemistry but not (usually) in Biology.
Question 9 assessed misconceptions in the energy changes that occur during bond breaking and bond formation. There were two correct answers in terms of the energetic of the reaction, namely A and C, but only A gave the correct explanation that bond breaking requires energy rather than releases energy. In fact, 47.1% of the students having Biology only, managed to understand that the energy needed is less than the energy released (since the reaction gives out heat) but they chose to explain it through option C, which gave the wrong explanation as to which process – bond formation or bond breaking – requires energy. This shows that the misconception of the release of energy during bond breaking was more evident in the Biology only students rather than the Biology and Chemistry ones.
Another important observation is that students managed to achieve a frequency of correct answers of 50% or higher, in only one fourth (25%) of the test questions, that is in three out of twelve questions. This suggests that more than 50% of the population of students involved have misconceptions in the four main chemical principles considered in this study.
As can be seen in Figure 2 below, In general, the girls performed better than the boys since in more than half of the questions, the percentage of correct answers exceeded the 50% mark. This result coincides with the 2007 TIMMS data, where it is reported that girls outperformed boys in both Biology and Chemistry.

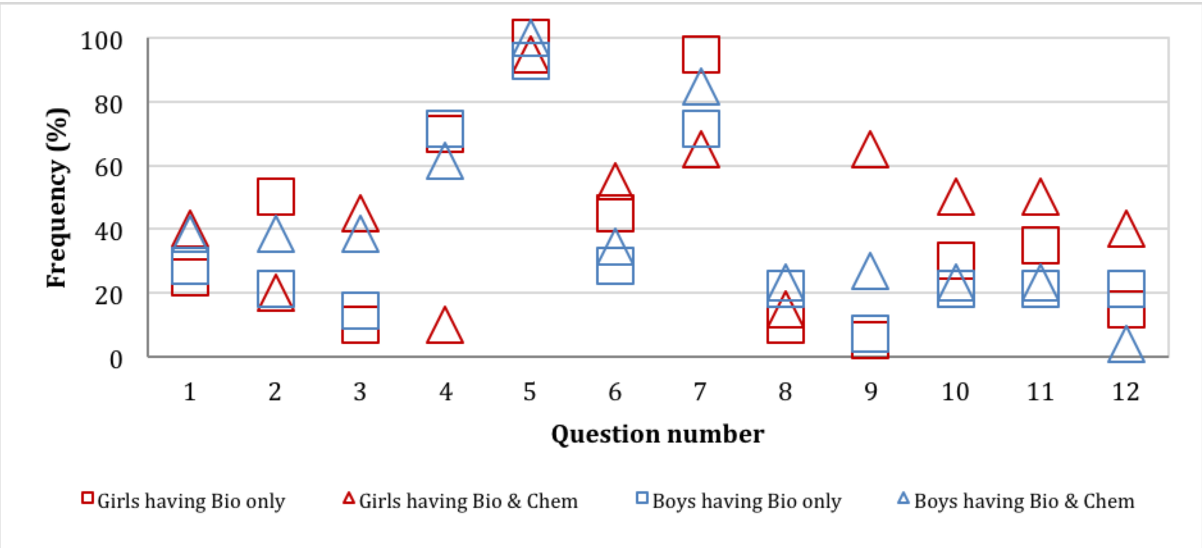

Fig. 2 Graph showing percentage frequency of correct answers per question, by gender and subject choice

This may be due to the fact that, since the nature of the test required a certain extent of reading and comprehension, boys might have been slightly disadvantaged when compared to girls. The general trend is that girls outperform boys in the aforementioned skills (Scantlebury, 2012). Another possible explanation for this result is that, since the Chemistry principles tested in this multiple-choice test are relevant to Biology, girls were in a better position to ‘compete’ with the boys, since they usually prefer and perform better in Biology (Scantlebury, 2012; Cheung, 2009). The plot in Figure 4 shows that the issue of subject choice seemed to play a bigger role on the girls’ performance with respect to the boys. One notes that in the majority of the questions, there was a greater difference in the percentage frequency of correct answers between girls having Biology only and Biology and Chemistry, in comparison to the corresponding two groups of boys.

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