Difficulties Experience by Science Foundation Students on Basic Mendelian Genetics Topic: A Preliminary Study

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Abstract
This paper aims to report and identify the difficulties experienced by Science Foundation students in understanding basic Mendelian Genetics based on their ability to solve three types of basic Mendelian Genetics problems. The problems given are; a monohybrid cross and two dihybrid cross cases. Result shown that 52.6% students were able to solve all the given problems while another 47.4 % had difficulties to solve at least one of the given problems. Among the students that had difficulties to solve the given problems, 4.4% students had difficulties to solve Type 1 problem, 13.3% students had difficulties to solve Type 2 problem, 15.6% students had difficulties to solve Type 3 problem, 8.9% students that had difficulties to solve both Type 1 and 3 problems, 40% students had difficulties to solve both dihybrid cross Type 2 and 3 problems, and 17.8% students were unable to solve all the given problems. E(X) or number of questions that the Science Foundation students had difficulties to solve is 0.874. The standard deviation for number of questions that the Science Foundation students had difficulties to solve is 1.842. In solving basic Mendelian Genetics problems, we expected students were able to solve the problems given and also can clarify the techniques used in term of genetic context. The initial finding reported in this study may be used to have a better understanding on students' ability and problem solving skills in learning genetics.

Introduction

There are many highlights in scientific advances related to genetics, for example, assessment on genetic influence on cognitive abilities, genetic background of illness including ebola, and gene editing in human zygote (Plomin *et al.*, 1994; Gire *et al.*, 2014; Liang *et al.*, 2015). However, genetics also has been identified as the most problematic topics in learning biology for secondary school and university students, and as well as teaching for teachers (Altunoglu & Seker 2015; Bahar *et al.*, 1999; Finely *et al.*, 1982; Haambokoma, 2007; Johnstone & Mahmoud, 1980).

In the earlier report, Knipples (2002) had identified five problems in genetics education; the domain specific vocabulary and terminology, the mathematical part in executing Mendelian genetics tasks, the cytological process, the abstract nature of the subject, and the complex nature of genetics. Other than that, problems such as difficulties in understanding concepts such as genetic crosses, genetic terms, cell division, and mutation are also consider as hurdles for students in learning and understanding genetics (Haambokoma, 2007). Teachers' inability to teach, fast deliberation by teachers, and inadequate learning time allocated for teachers to teach the topics are among causes that contributed to these obstacles (Haambokoma, 2007).

Genetic Inheritance is one of the topics covered in Development and Genetics (SB0034) course at Foundation Science, Universiti Malaysia Sabah during third semester. Genetic inheritance is explaining how characteristics can be inherited from parents to children and from generation to generation by using fundamental laws of classical genetics or Mendelian genetics. This chapter also integrates the concept of inheritance that deviated from Mendelian classical laws and incorporates theory of chromosomal inheritance by Thomas Hunt Morgan. In this course, students are expected to understand few intended learning outcomes; Mendel's first and second laws, and relation of both laws to meiosis. Hence, the objective of this study is to report and identify the difficulties experienced by Science Foundation students in understanding basic Mendelian Genetics by evaluating their ability to solve three types of basic Mendelian Genetics problems.

Methodology

This paper adopts method used by Stewart (1982) in examining students' knowledge and problem solving strategy by providing three basic genetic problems. For this report, a quiz which consisted of three types of genetics problems (Table 1) was given to 95 students in a class. Prior to this quiz, students were given four hours of lecture class, tutorial class, and problem-based learning assignment on Genetic Inheritance topic.

Table 1. Types of genetics problems in a quiz given to Science Foundation students

	Types of problem
Type 1	Monohybrid cross. Given the following parents genotypes, TT and tt. Where; T allele is for tall, and t allele is for short. Tall is dominant over short. What are the possible genotypes and phenotypes for F1 and F2 crosses?
Type 2	Dihybrid cross. Given the following parents genotypes, YYSS and yyss. Where; Y allele is for yellow, y allele is for green, S allele is for smooth, and s allele is for wrinkled. Yellow is dominant over green and smooth is dominant over wrinkled. What are the possible genotypes and phenotypes for F1 and F2 crosses?
Type 3	Dihybrid cross. Given the following parents genotypes, BbDD and bbdd. Where; B allele is for purple stem, b allele is for green stem, D allele is for smooth leaf, and d allele is for dented leaf. Purple stem is dominant over green stem and smooth leaf is dominant over dented leaf. What are the possible genotypes and phenotypes for F1 from these crosses?

For statistical analysis we used a theoretical approach. Let the discrete random variable X is Number of questions of the Difficulties Experienced by Science Foundation Students

Definition 1

If the discrete random variable X has following probability distribution

$\boldsymbol{x}$	x_1	x_2	x_3	$\cdots$	x_n
$\boldsymbol{P(X = x)}$	p_1	p_2	p_3	$\cdots$	p_n

Expectation of the discrete random variable X:

$$\mu = E(X) = x_1p_1 + x_2p_2 + x_3p_3 + \cdots + x_np_n$$

$$= \sum x_ip_i \qquad \text{for } i = 1, 2, 3, \dots, n$$

Definition 2

If the discrete random variable X has following probability distribution

$\boldsymbol{x}$	x_1	x_2	x_3	$\cdots$	x_n
$\boldsymbol{P(X = x)}$	p_1	p_2	p_3	$\cdots$	p_n

The variance of a discrete random variable X:

$$Var(X) = \sigma^2 = \sum x_i{}^2p_i - \{E(X)\}^2 \qquad \text{where } i = 1, 2, 3, \dots, n$$

Definition 3

The standard deviation of X:

$$\sigma = \sqrt{Var(X)}$$

The statistical result will show expected value and the standard deviation for number of questions that the Science Foundation students had difficulties to solve. If a high proportion of data points lie near the mean value, then the standard deviation is small. An experiment that yields data with a low standard deviation is said to have high precision.

Result

All students used both Punnet square method and algebraic method, or either method to solve all three types of problems. Students were expected either they were able to solve all the given problems or they failed to solve at least one of the given problems. Fifty out of 95 (52.6%) students had no difficulties to solve all the given problems while another 45 students (47.4%) had difficulties to solve at least one of the given problems.

Among the 45 students that had difficulties to solve the given problems, 4.4% students had difficulties to solve Type 1 problem, 13.3% students had difficulties to solve Type 2 problem and 15.6% students had difficulties to solve Type 3 problem as observed in Table 2. Apart from that, there were 8.9% students that had difficulties to solve both Type 1 and 3 problems, 40% students had difficulties to solve both dihybrid cross Type 2 and 3 problems while another 17.8% students were unable to solve all three types of the given problems.

Table 2. Percentage of students that gave false answers based on type of problems

Type of problems	Number of students that had difficulties to solve the given problems (N=45)	Percentage of students that had difficulties to solve the given problems, (%)
1	2	4.4
2	6	13.3
3	7	15.6
1 and 2	0	0.0
1 and 3	4	8.9
2 and 3	18	40.0
All	8	17.8

Table 3. Probability for number of questions that the Science Foundation students had difficulties to solve.

Number of questions	0	1	2	3
Probability	0.526	0.158	0.232	0.084

From table 3, we found that the probability of students to have no difficulties in solving the given questions is 0.526, 0.158 for students that had difficulties to solve only one question, 0.232 for students that had difficulties to solve two questions and 0.084 for students that had difficulties to solve all the given questions. An expected value, $E(X)$ for number of questions that the Science Foundation students had difficulties to solve is 0.874 and the standard deviation for number of questions that the Science Foundation students had difficulties to solve is 1.842.

Presented below are common errors done by students while solving the problems given. Error 1 shows mistake done by students in solving monohybrid cross. This indicates that students were not successful to understand the concept of meiosis and Mendel's law of segregation in constructing Punnet square. Complications to understand the meaningful concept of segregation in meiosis also occur when students tried to solve problem for dihybrid cross as shown in Error 2 and Error 3.

Error 4 shows dihybrid cross problem solving using algebraic method in which students often place wrong allele symbol to represent gamete that carries two characteristics i.e. colour of stem, and margin of leaf.

Error 1: Monohybrid cross, F2

	Tt	Tt
Tt	TTtt	TTtt
Tt	TTtt	TTtt

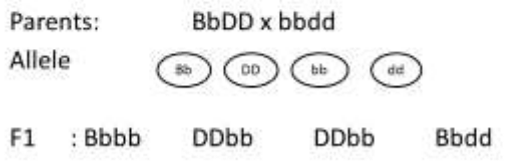
Error 2: Dihybrid cross, F1

	y	y	s	s
Y	Yy	Yy	Ys	Ys
Y	Yy	Yy	Ys	Ys
S	yS	yS	Ss	Ss
S	yS	yS	Ss	Ss

Error 3: Dihybrid cross, F2

	SS	ss
YY	YYSS	YYss
yy	yySS	yyss

Error 4: Dihybrid cross, F1, Algebric method



Discussion

In learning genetics, it is vital for students to know and understand the terminologies used in classical genetics (Bahar *et al.*, 1999). Prior knowledge on these important terminologies would enable student to understand classical genetics problems e.g. monohybrid cross and dihybrid cross. Nevertheless further survey must be conducted in order to determine student knowledge on fundamental genetics terms e.g. homozygote and heterozygote (Bahar *et al.*, 1999). Even though students by default would use Punnet square in solving and answering genetics question, this is not necessary a gauge or a reflection to their understanding on nature of meiosis in genetics (Kinnear, 1983). The teachers' factors should also be highlighted in discussing students' difficulties in learning genetics (Cimer, 2012; Haambokoma, 2007). Past studies reported that the teachers' understanding level could contribute to student's misconceptions, i.e. concepts related to cell division (Altunoglu & Seker, 2015; Flores *et al.*, 2003). Students tend to memorize biological facts, a common practice in learning biology among students, due to their failure in relating biology lesson with real life (Cimer, 2012).

Based on the result from table 3, the expected value, $E(X)$ for number of questions that the Science Foundation students had difficulties to solve is 0.874 which indicates that the students from Science Foundation had difficulties to solve 0.874 questions from the total questions given. The standard deviation for number of questions that the Science Foundation students had difficulties to solve is 1.842. Hence, we found that the spread number of questions that the Science Foundation students had difficulties to solve with the expected mean of 0.874 is 1.842. From the result, the experiment yields data that has a low standard deviation, 1.842, which indicates that it has a high precision.

Although it is premature to draw any insightful claims, yet difficulties encountered by this sample group of students should be well addressed and further studied. Particularly when there are 40% of students encountered difficulties to answer both of the given problems based on dihybrid cross. Stewart, (1982) had supplemented his similar qualitative findings with students' statements obtained through interviews. From those interviews, it was noted that students did have some knowledge on meiosis but did not know how to relate it to Mendelian Genetics (Stewart, 1982). Other than interviews, a survey could be used to investigate nature and causes of learning difficulties experienced by students (Haambokoma, 2007). However, there were no interviews or survey conducted among students who participated in this study. Their difficulties in learning Genetic Inheritance are only observed through written answers.

Conclusion

In summary, the study managed to report and identify the difficulties experienced by Science Foundation students in understanding basic Mendelian Genetics based on their ability to solve three types of basic Mendelian Genetics problems. Expected value, $E(X)$ show for number of questions that the Science Foundation students had difficulties to solve is only 0.874. For students to have difficulties to solve 0.874 questions from the total questions given is a good indication to show that most of the Science Foundation students were able to understand and solve the given questions. Students were mostly to have difficulties in solving Type 2 and Type 3 dihybrid cross problems compared to Type 1 monohybrid cross problem. The type of common errors done by the Science Foundation students points out that the students were mostly unable to relate the concept of meiosis in learning genetics and to understand Mendel's law of segregation causing their failure to solve both monohybrid and dihybrid cross problems. Hence, the students understanding in both the concept of meiosis and the law of segregation should be improved. The involvement of lecturers in guiding students to better understand genetics by using visual aid or relating biology lesson with real life may also be emphasized. Further studies should be carried out based on the difficulties experienced by Science Foundation students in solving basic Mendelian Genetics problems in order to evaluate and tackle the factors that are causing their failure in understanding basic Mendelian genetics.

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