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Incorporating case studies into an undergraduate genetics course

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Genetics is considered one of the most challenging courses in the biology curricula at both the secondary and post secondary levels. Case based teaching has been shown to improve student perception and performance outcomes in both non-science and science courses. Thus in an effort to improve outcomes, case studies were integrated into an undergraduate genetics course as a supplement to lecture and replacement to recitation. Student perception and performance when case studies were used was compared to two previous years before the incorporation of case studies. Student course evaluations, pre and post surveys of student knowledge, and exam scores indicated that when case studies were used student perception improved while student performance showed mixed results.

Keywords: case studies, case-based teaching, genetics

I. Introduction.

The discipline of genetics serves as the core of biology education by providing a set of unifying concepts essential for the other disciplines in biology (AAAS, 1993; Banet & Ayuso, 2003; Tsui & Treagust, 2004a). Genetics is considered one of the most important and difficult courses to teach and learn (Johnstone & Mahmoud, 1980, Finley, Stewart, & Yarroch, 1982; Kinfield, 1994; Bahar, Johnstone, & Hansell, 1999; Lewis & Wood-Robinson, 2000; Banet & Ayuso, 2000; Tsui & Treagust, 2004). One reason for this difficulty is the complex and abstract nature of many of the concepts in genetics. Understanding these concepts require multi-level thinking described as the micro (chromosomes, gametes), macro (organismal), and molecular (DNA, genes) levels. Transitioning between these levels may be done with ease by instructors but can be a major challenge for students (Marbach-Ad & Stavy, 2000; Duncan & Riser, 2007).

Students struggle to make connections between concepts because instructors and textbook authors often compartmentalize topics (Griffith, 2008). For example meiosis and inheritance (Wynne, Steward, & Passmore, 2001; Knippels, 2002) or genes and chromosomes (Lewis & Wood-Robinson, 2000) are often presented as four separate topics instead of being integrated. This instructional separation of key concepts does nothing to foster the multilevel thinking necessary for proficiency in genetics. Without connections between concepts, most genetics courses end up being an encyclopedia of genetics information, understanding of which is often complicated by the discipline-specific vocabulary and terminology (Knippels, Waarlo, & Boersma, 2005; Griffith, 2008).

Mastering genetics requires the application of complex content to the complex task of problem solving-an integral part of genetics especially Mendelian genetics (Collins & Stewart, 1989). However, unlike problems in mathematics and physics that have one correct answer usually derived by a clearly defined algorithm, there may be more than one approach to solving a problem in genetics (Collins & Stewart, 1989). Proficiency in problem solving-the primary means by which understanding is assessed in genetics is an atypical method of assessment in biology and requires higher levels of Bloom’s taxonomy. Thus traditional study habits such as

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memorization are ineffective (Griffith, 2008). It is therefore not uncommon for students who perform well in other biology courses to not perform as well in genetics (Banet & Ayuso, 2000; Griffith, 2008).

With genetics playing such a central role in biology, genetics education reform is clearly needed. Recommendations for reform include strategies that teach genetics using a conceptual approach with intentional emphasis on integration of concepts (Banet & Ayuso, 2003, Lewis, Leach, & Wood-Robinson, 2000b; Chattopadhyay, 2005). Learning genetics through the discussion of social issues is one approach proposed by Finkel (1996) and by Lewis and Wood-Robinson (2000). Other studies recommend a scientific approach to understanding, described as inquiry-based pedagogy (Finkel 1996; Ibáñez-Orcajo & Martinez-Aznar, 2005). With this approach, students gain knowledge through analysis rather than algorithms thus developing their analytical skills (Lewis & Wood-Robinson, 2000). An example of this approach is case based teaching (CBT). CBT encourages active learning and requires students to analyze and think critically, thus fostering the development of a higher order of thinking (Herried, 1994, Wood &Anderson 2001; Dori, et. al., 2003; Weil, et. al., 2001; Handelsman, et. al., 2007). Case studies help students recognize the relevance of the course material and can be used to promote collaborative learning, an approach preferred by college students (Cabrera, et. al., 2002). Thus this approach has the potential to improve student perception of the course (Seymour & Hewitt, 1977; Hayes, 2002).

CBT has been used for many years in business, law and medical schools, however until relatively recently its use in the science curriculum remained sparse (Gabel, 1999). A number of studies have reported the positive benefits of using case studies in science courses. For example, Cliff and Wright (1996) reported improvement in exam performance in an anatomy and physiology course after case studies were introduced. Similar improvements were observed in a biochemistry course when CBT pedagogy was used (Cornely, 1998; 2003). Even among non-science majors, CBT proved to be beneficial by leading to increased knowledge and understanding and the development of higher order thinking skills in a biotechnology course (Dori, Tal, & Tsaushu, 2003). As in non-science courses, CBT has been associated with positive student perception of an upper-division cell and molecular biology lab course (Knight, et. al., 2008). Despite these examples of the use of CBT in science courses, studies reporting the impact of CBT in genetics courses are limited in their scope. For example, in the 2009 paper "Constructing and Using Case Studies in Genetics to Engage Students in Active Learning," Styer discusses the use of case studies in the teaching of genetics and describes one method used to administer the case. However the paper does not report on the impact of CBT on student outcomes. Holtzclaw, et. al., (2006) assessed students confidence in using case-based learning to better understand genetics when used to introduce a bioinformatics component in the course and reported an improvement in confidence levels. To my best knowledge, no study, has reported on the impact of the incorporation of CBT on student perception and performance in an undergraduate genetics course. Thus, in an effort to improve student perception and performance outcomes in genetics, CBT was used to introduce and expand on several topics in the course and the effect of this pedagogical approach on student perception and performance was assessed by comparing outcomes before (2007 and 2008) and after (2009) the incorporation of CBT.

II. Method.

A. Course Description and Content.

At Andrews University, genetics is a three-credit core course for biology majors. It covers the mechanisms of heredity in light of molecular and population genetics. The prerequisites are an introduction to biology course that contains a significant genetics component, and completion of or simultaneous enrollment in first semester general chemistry. The course instruction consists of two 50-minute weekly lectures on Monday and Wednesday, a three-hour lab on Thursday and a 50-minute weekly recitation on Fridays. The first 1/3 of the course covers classical genetics and the remaining 2/3 focuses on molecular and population genetics. In 2009, case studies were used to supplement lectures and replace Friday recitation.

B. Participants.

During 2007, 48 students were enrolled in this genetics course, 42 of which were biology majors while the remaining 6 included other science and non-science majors. There were 33 sophomores, 6 juniors and 9 seniors. Of the 55 students enrolled in the course in 2008, 46 were biology majors while the remaining 9 held majors in other science and non-science disciplines. The class standing distribution was as follows: 34 sophomores, 15 juniors and 6 seniors. Of the 51 students enrolled in 2009, 37 were biology majors and the remaining 14 included majors in science and non-science disciplines. This class consisted of 27 sophomores, 12 juniors, 9 seniors and 3 post-graduate or graduate students.

C. Cases Used.

All cases were obtained from the National Center for Case Study Teaching in Science (NCCSTS) Case Study collection website (http://sciencecases.lib.buffalo.edu/cs/) hosted by the University of Buffalo. Teaching notes and Answer keys for all cases are password protected and available to faculty only. The cases used were as follows:
1. Those Old Kentucky Blues (Leander & Huskey, 2008), an interrupted case used to address concepts in Mendelian inheritance, extensions to Mendelian inheritance and allelelism.
2. Cross- Dressing or Crossing-Over (Knabb & Sharp, 2008), a clicker case was used to expand on Meiosis and the basis of sex determination in mammals.
3. Colon Cancer (Casper, 2008) was used as an introduction to the NCBI database and the associated bioinformatics tool and included pedigree analyses.
4. Living With Her Genes (Gildensoph, Stanford, & Wygal, 2008) was used to reinforce several topics such as Mendelian inheritance, allelism, DNA composition and gene expression.
5. Two Peas in a Pod? (Welsh, 2003) was used as a follow up on DNA analysis, recombinant DNA technologies and opened up discussion on the ethics of reproductive technologies.
6. The Death of Baby Pierre (Herreid, 1999) was used as part of the first exam and reinforced concepts in Mendelian Inheritance and the rules of probability.

D.Case Methods Used.

Cases were administered using the following methods described by Herreid (2005):
1. The Small Group Method: Permanent groups were formed the first day of class and consisted of six to seven students and at least one male and one female. Cases were assigned to each group at the beginning of class and time was given for analysis and discussion within the group.

2. *The Interrupted Case Format* was always used with the small group method. With this format, information was given in segments followed by questions after each segment. Groups were evaluated by answers given by the group-designated spokesperson or written answers submitted jointly at the end of class.
3. *Mixed Method*: Involved a combination of the Lecture, Directed and Whole Class Discussion Methods (Herreid, 2005). Cases were presented using a series of power point slides punctuated by close-ended questions that students responded to using personal response systems (clickers), followed by whole class discussion.
4. *Individual Method*: With this method cases were assigned as homework and students evaluated by answers to homework questions turned in one week after assignment.

E. Assessment.

The impact of incorporating case studies on student perception of the course was assessed by the use of the university developed course evaluation instrument administered at the end of the course. The percentage of students completing the survey in 2007, 2008, and 2009 were 81% (39 of 48), 56% (31 of 55) and 84% (43 of 51) respectively. On the first and last days of the course in 2009, the impact of CBT on student knowledge of specific topics was assessed via a survey containing one question on each of the following topics in genetics: Mendelian Inheritance, Alleleism, Exceptions to Mendelian Inheritance, Gene Linkage, DNA Structure and Gene Expression. Students responded anonymously and the percentage of accurate responses was calculated. The number of students completing the pre-course survey was 46 (90%), while 44 students (86%) completed the post-course survey. A comparison of grades before and after CBT incorporation also provided insight on the impact of CBT on student performance.

III. Results.

A. Course Evaluations.

On the university administered online course evaluation used to assess student perception, students were asked to indicate their extent of agreement or disagreement with each statement. Table 1 reports a comparison of student responses to statements before (2007 and 2008) and after (2009) case studies were incorporated. The percentage of students that agreed or strongly agreed that the learning objectives were clearly stated was highest in 2007 (79%) compared to 2008 (68%) and 2009 (72%). In 2007, 59% of students responding agreed/strongly agreed assignments were beneficial for learning the subject matter. That percentage decreased to 52% in 2008 then increased to 70% in 2009. In 2007, 41% of students agreed/strongly agreed the course helped them think clearly while 36% had the same response in 2008. In 2009, 56% had the same response to the somewhat related statement-‘the course improved my ability to analyze and evaluate information’. Agreement with the statement-Evaluation methods were fair and appropriate, were highest in 2009 at 67% compared to 2007 and 2008 which were 43% and 39% respectively.

Table 1. Student responses to selected course evaluation statements.

2007 (N=39)						
	SD	D	N	A	SA	N/A
The learning objectives of this course were clearly stated	0	5	15	64	15	0
The assignments were beneficial for learning the subject matter	8	13	18	44	15	0
The course helped me think clearly	13	31	15	33	8	0
Evaluation methods were fair and appropriate	26	15	15	33	10	0
2008 (N=31)						
	SD	D	N	A	SA	N/A
The learning objectives of this course were clearly stated	10	7	16	45	23	0
The assignments were beneficial for learning the subject matter	10	23	16	32	19	0
The course helped me think clearly	13	13	39	29	7	0
Evaluation methods were fair and appropriate	19	26	16	26	13	0
2009 (N=43)						
	SD	D	N	A	SA	N/A
The learning objectives of this course were clearly stated	0	2	26	65	7	0
The assignments were beneficial for learning the subject matter	0	5	26	51	19	0
*The course strengthened my ability to analyze and evaluate information	2	9	33	47	9	0
Evaluation methods were fair and appropriate	0	7	26	58	9	0

SD, strongly disagree, D, disagree, N, neutral, A, agree, SA, strongly agree, N/A, not applicable (*) Indicate statement unique to that year.

Students were also asked to write additional comments on the course. Following is a list of all unsolicited comments made regarding case studies.

"I liked the case studies."
"I really enjoyed the case studies."
"I like the case studies. I thought they related well to what we were learning."
"Case studies were interesting."
"The case studies are especially enjoyable."
"Case studies were very informative."
"I would like to see more case studies."

B. Pre and Post-Surveys.

Of the 51 students enrolled in the course, 46 (90%) completed the pre-course survey, while 44 (86%) completed the post-course survey. The results (Figure 1) show that the percentage of accurate responses increased in all topics except DNA structure where the percentage of accurate responses in the pre-survey was the highest (70%). The highest fold increase (4.7) was seen on the Extensions to Mendelian Inheritance question followed by the Gene Linkage question, which had a 4.4 fold increase. Accurate responses on the Allelism, Gene Expression and Mendelian Inheritance questions increased 3.2, 2.0 and 1.2 fold respectively.

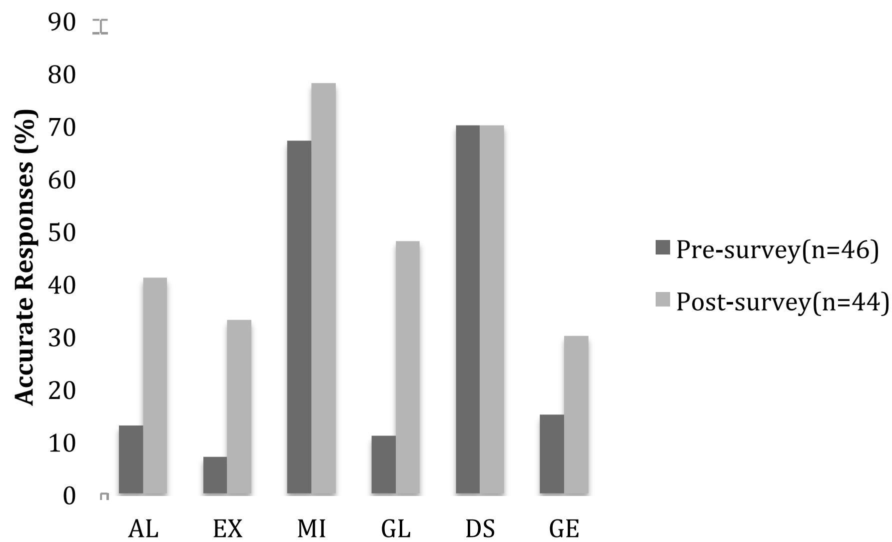

Figure 1. Pre- and post-course survey results of student knowledge in 2009. Forty-six students completed the pre-course survey, and 44 students completed the post-course survey. Students were questioned on Allelism (AL), Exceptions to Mendelian Inheritance (EX), Mendelian Inheritance (MI), Gene Linkage (GL), DNA Structure (DS) and Gene Expression (GE)

C.Student Grades.

Final grades were based on four section exams, one cumulative final, homework, lab reports, quizzes, and case studies analyses (2009 only), which contributed to 6% of the final grade in 2009. Figure 2 shows the class performance during the three years covered by this study. In 2009, 43% of the students earned a grade of *A*, while in 2007 and 2008 the percentage of students earning a grade of *A* were 33% and 30% respectively. In 2009, 7% of students earned a grade of *F* while in 2007 and 2008, the percentage of students earning a grade of *F* were 13% and 14% respectively. The difference in class averages (Figure 3) was not significant $t_{(104)} = 1.32$, $p > 0.05$. Only the class averages for years 2008 and 2009 are shown in Figure 3.

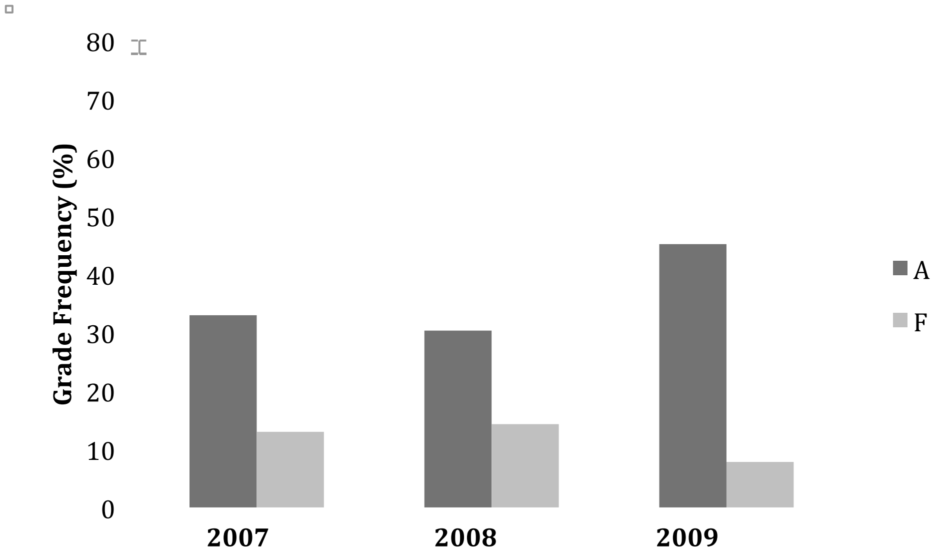

Figure 2. Final grade frequencies of grades *A* and *F* before and after incorporation of CBT. 2007, n= 48; 2008, n= 55; 2009, n=51.

Figure 3. Class averages before and after the incorporation of CBT. 2008, n-55, Mean ± SE= 75 ± 2; 2009, n= 51, Mean ± SE= 79 ± 2.

IV. Discussion.

This study reports the impact of CBT on student perception and performance in an undergraduate genetics course and thus adds to the scholarship of teaching and learning (SoTL) knowledge base. In an effort to improve student perception and performance outcomes in genetics, CBT was used as a supplement to traditional lectures to introduce and expand several topics in the course. While CBT is commonly used in various disciplines such as business, medicine and law, its use in science remains limited. Anecdotal responses from science teachers regarding the minimal use of case studies is based in the fear that they will not be able to cover all the required course content. The director of the National Center for Case Study Teaching in Science, Clyde Herreid, (1994) acknowledges that the same amount of information cannot be covered when CBT is used. However, the approach used in this study, which was to use CBT as a supplement to lecture, the required and expected course content was not compromised. In fact, additional topics such as bioinformatics and cancer genetics were covered as a direct result of the case studies used.

The current study supports prior findings that CBT improves students' perception of a course (Seymour & Hewitt, 1977; Hayes, 2002; Hudson & Buckley, 2004; Knight, et.al., 2008). Although there was initial reluctance by some students during case study sessions, as the course progressed, most became fully engaged and even requested additional case studies. In addition to the comments regarding case studies on the student evaluations, which were all positive (see list of student comments in results), comments regarding the course such as: *"Genetics has never been my strong point but it was interesting to delve deeper into material that I would have no interest in otherwise"* and *"It was a difficult course, but it has taught me a lot of new concepts that I wasn't able to understand before"*, indicate a positive perception of the course and represents a marked improvement compared to previous years. The student evaluations also showed that the percentage of students agreeing that the course strengthened their analytical, problem-solving and critical thinking skills increased the year case studies were used. These are skills enhanced by CBT (Herried, 1994; Wood & Anderson, 2001; Dori, et. al., 2003; Weil, et. al., 2001; Handelsman, et. al., 2007) and necessary for success in genetics. In addition, despite the fact course assignments were the same during the three years of the study (with the exception of the case studies in 2009), the percentage of students agreeing that assignments were beneficial for learning, increased the year case studies were used. There are however limitations to the conclusions that can be made from these results regarding the impact of case studies on student perception, since none of the evaluation statements were designed to directly solicit responses regarding case studies. Therefore to better gauge the impact of case studies on student perception, pre and post SALG (Student Assessment of Learning Gains) surveys will be used in the future. This survey can provide information that more directly link case studies to students' perception (Galluci, 2007; Seymour, Daffinrud, Wiese, & Hunter, 2000).

Pre and post surveys were used to measure student performance in six topics, five of which were covered in cases analyzed in the course. The improvement in student knowledge observed cannot however be attributed solely to the use of case studies since the second highest improvement was seen on the Gene Linkage question- a topic not covered in any of the cases used. However, a comparison of the different CBT methods used in this study showed that students were most engaged in the most commonly used method in this study- the interrupted case format with the small groups. This method encourages inquiry and may foster the development of analytical and critical thinking skills. Therefore it may be suggested that the improvement observed in topics not specifically covered in case studies may be due to the application of these skills. Thus case studies may have indirectly led to better performance on all topics assessed.

Despite the grade criteria and scale remaining unchanged, the percentage of students earning a grade of *A* increased and the percentage failing the course decreased the year case studies were used. However, statistical analysis showed the class average improvement was not statistically significant suggesting that for a sizable proportion of the students, skills encouraged by CBT and beneficial for learning genetics were probably not improved or did not translate to improved test performance. One possible explanation for this could be the discomfort by both the teacher and students in using this pedagogy and as a result the benefits of CBT was not more widely experienced. Making case based pedagogy the predominant mode of instruction can decrease the awkwardness of using this pedagogy (Herreid, 1994, Yadav, et.al., 2007). Therefore future endeavors include increasing the number of case studies used, specifically using the interrupted case format with the small group method. This method provides structure to the discussion and allows for intentional content coverage while mimicking the way scientists have to analyze problems since information is provided in segments. It also keeps feed-back time to a minimum.

According to the College Learning for the New Global Century Report, the four essential learning outcomes of a twenty-first century college education are: (1) Knowledge of human cultures and the physical and natural world, (2) Intellectual and Practical skills, including inquiry and analysis, critical and creative thinking, teamwork and problem solving, (3) Personal and Social responsibility and (4) Integrative Learning demonstrated through the application of knowledge to complex problems (National Leadership Council, 2007). As previously mentioned, CBT can promote at least two of these outcomes- Intellectual and Practical skills and Integrative Learning. The findings of this study provide evidence that CBT when used as a supplement to lecture is a good method for teaching and learning genetics at the college level. It encapsulates strategies proposed for reforming genetics education such as inquiry-based learning, conceptual learning with integration of concepts and learning via discussion of social issues. Thus although there are limitations to the CBT pedagogy the benefits obtained are worth it's implementation in college genetics courses.

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