Do Females Learn Biological Topics by Rote More Than Males?

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STUDENTS were asked to write a summary of everything they could about meiosis. The following is one student's response:

Meiosis occurs in 2 sets of 5 phases

Interphase, Prophase, Metaphase, Anaphase, Telophase 2nd interphase, prophase,

metaphase, anaphase, telophase.

In describing meiosis, this student successfully reported the names of the phases, including interphase or the "resting" stage. Unfortunately, the explanation does not show a very meaningful understanding of meiosis. This student did not indicate knowledge, for example, of where meiosis occurs (i.e. in the body, in cells); how it occurs (i.e. chromosomes duplicate, the primary sex cell divides twice); what the results of meiosis are (i.e. gametes with halved numbers of chromosomes); and most importantly, why meiosis occurs in the first place (i.e. to prepare a cell with half the chromosome number for union with another gamete in fertilization).

The rote response of the above student was not unusual. Similar responses were given by students at other schools in other parts of the country whether the test was administered orally or in writing. This kind of response, however, should cause educators to consider the kind of biology learning we hope to foster among students. Future science learning depends on students making sense of their experiences in the natural world. Students should acquire new knowledge, not by memorizing isolated facts, but through the construction of relationships among information, concepts and ideas (Novak 1988). Further, the interrelated understandings students acquire should help them generate new ideas in science. Ausubel (1963) called students' formulation of interrelated understandings among information, concepts and ideas, "meaningful learning."

Although some students do attempt to meaningfully learn new information and experiences in science classrooms, many students do not (Cavallo 1991; Cavallo & Schafer, in press; Novak 1988). Many students tend to learn science by rote, that is, by memorizing facts without relating new information, concepts and ideas to what they have previously learned or may already know (Novak 1988). Consistent rote learning, however, may make it difficult for students to learn increasingly more complex scientific concepts (Novak 1988).

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Furthermore, there is some indication that females may learn science information and concepts by rote more than males (Ridley & Novak 1983). Rote learning is thought to occur more frequently among females because, more often than males, they may be socialized to "do as they are told" and not question authority. Conversely, it is generally acceptable for males to diverge from an authoritative way of thinking.

Questioning authority, however, is part of the very nature of science. Educators should encourage their students to question the findings of scientists, to struggle with ideas until they make sense, and to generate new ideas from what they have learned. Are females less likely than males to use this form of mental activity, or meaningful learning, in learning biology? This paper explored the learning approaches (meaningful, mid-range, rote) of males and females and their subsequent biology understanding and achievement.

A Study of Meaningful Learning

A study involving 140 high school biology students (70 males, 70 females) and four teachers (one male, three females) was conducted at a suburban high school in New York state. The students were enrolled in one of seven classes of the same college-entrance biology course taught by the teachers. The teachers in this study followed a departmentally designed syllabus, used the same examinations, and remained in sequence with their instructional topics throughout the year.

In this study, the teachers participated in a series of training sessions that prepared them to rate their students according to how each approached learning (meaningful, mid-range, rote). The teachers were given specific criteria for identifying meaningful and rote learning approaches based on previous research (Ausubel 1963; Novak 1988; Novak & Gowin 1984)

Table 1. 2 × 4 chi-square analysis of the biology teachers (n = 4) ratings of their male and female students' learning orientations.

	Learning Orientation Teacher Ratings				
	More Rote	*Less Rote*	*Less Meaningful*	*More Meaningful*	*n*
Females	23	20	13	14	70
Males	11	14	26	19	70
n	34	34	39	33	140

$X^2 = 10.385$, $p = .016$.

and on constructs determined valid by two science educators and two classroom science teachers in a pilot study (see Cavallo 1991). Teachers were to disregard discipline aspects and the grades their students earned in their course work. The criteria teachers used focused on evidence they obtained that helped them determine whether individual students tended to learn by memorizing facts in biology (rote) or whether they tended to learn by attempting to make sense of information and by formulating interrelationships between science ideas and information (meaningful). The teachers' ratings of their students were obtained near the end of the school year (April) and after participating in the training sessions over a two-month period. The teachers rated each of their students according to the following scale: 1 = More Rote, 2 = Less Rote, 3 = Less Meaningful, 4 = More Meaningful. The results of teacher ratings of their male and female students are shown in a 2 × 4 chi-square analysis in Table 1.

Table 1 shows a clear pattern in teachers' ratings of their male and female students' learning orientations. The teachers rated the females as being more rote in their learning orientation than the males. In other words, the teachers overall viewed females as more likely to memorize or learn by rote and males more likely to learn meaningfully or make sense of information when learning biology topics. The teachers' categorical ratings were collapsed to facilitate data interpretation, and these results are presented in Figure 1.

To determine the students' own perceptions of how they learn, they were given a questionnaire called the Learning Approach Questionnaire (LAQ) (Cavallo 1991; Cavallo & Schafer, in press; Donn 1989; Entwistle & Ramsden 1983). The LAQ is a 24-item subscale of a Likert instrument designed to measure students' orientation or tendency toward rote or meaningful learning (Cronbach alpha = .77). The scores students received on the questionnaire indicated their learning orientations according to the following scale: 1 = More Rote, 2 = Less Rote, 3 = Less Meaningful, 4 = More Meaningful. Students'

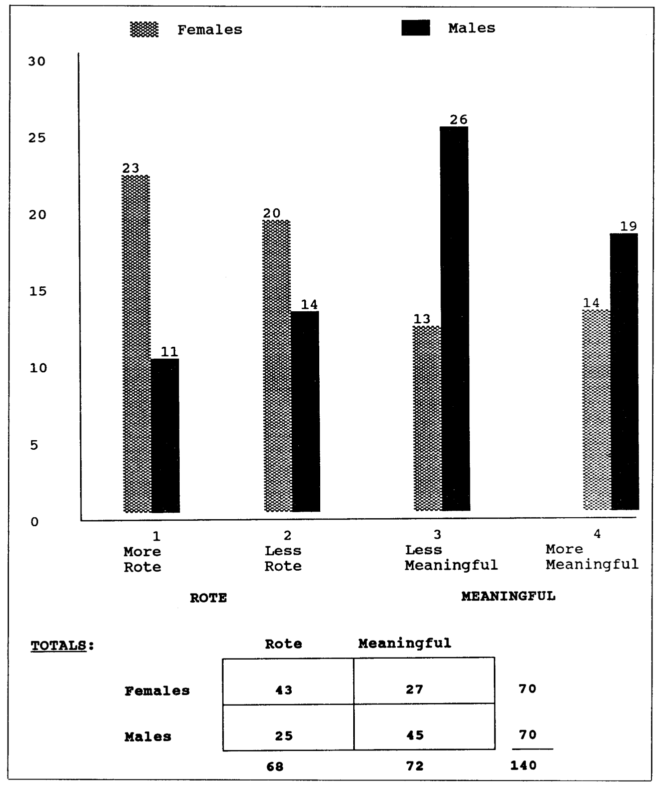


Figure 1. Biology teachers' (n = 4) ratings of their male and female students' (n = 140) learning orientations.

self-reported ratings of their learning orientations are shown in a 2 × 4 chi-square analysis in Table 2.

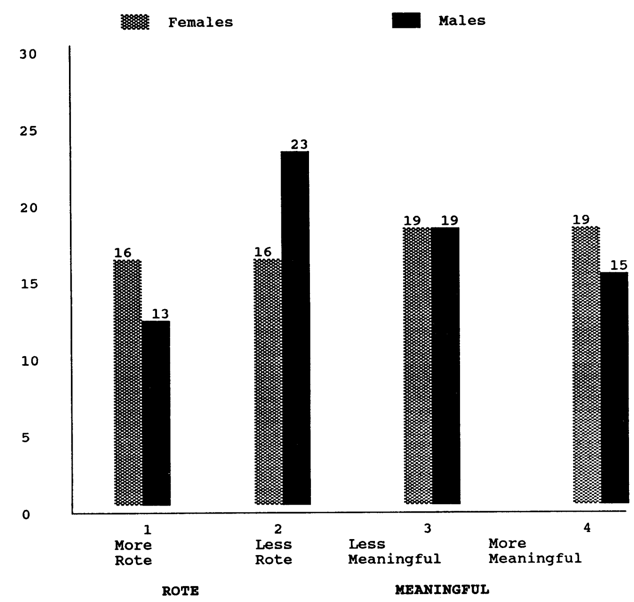
According to the results presented in Table 2, the students had a different view of their own learning orientations than did their teachers. Results of the students' self-reported questionnaire indicated no significant differences between the males' and females' learning orientations (see Table 2). Thus, the girls did not view themselves as learning in a more rote or a more meaningful way than did the boys. The students' ratings of their learning approaches were collapsed to facilitate data interpretation; these results are presented in Figure 2.

Which view of the students' learning is more appropriate, that of the teachers or the students? The

Table 2. 2 × 4 chi-square analysis of the student-reported ratings of their learning orientations on the Learning Approach Questionnaire.

	Learning Orientation Student Ratings				
	More Rote	*Less Rote*	*Less Meaningful*	*More Meaningful*	*n*
Females	16	16	19	19	70
Males	13	23	19	15	70
n	29	39	38	34	140

$X^2 = 2.037$, $p = .565$.



TOTALS:

	Rote	Meaningful	
Females	32	38	70
Males	36	34	70
	68	72	140

Figure 2. Student-reported ratings (n = 140) of their own learning orientations on the Learning Approach Questionnaire.

next phase of the study investigated students' performance on two biology tests with different question formats. The students were tested on selected topics in biology (meiosis and genetics) using an open-ended question format. Test scores were also obtained on the final state-administered biology examination that had a multiple-choice question format.

The open-ended tests, called mental model tests (Mosenthal & Kirsch 1992), asked students to explain everything they knew about the topic in question, in this case, meiosis; the use of Punnett square diagrams in genetics; and the relationships between these two topics. Students were asked to write as much as they could about the topics and to use diagrams to help with their explanations. They were also informed that grammar and spelling would not count against their grade. Students had practiced taking open-ended test questions prior to meiosis and genetics instruction. The students were familiar with the format and fully aware of the expectations for thorough and complete responses.

Students' mental model tests on the meiosis and genetics topics were coded using a standardized, objective system and scored (see Cavallo 1991). (Note: The procedure for coding and scoring mental model tests has been described in detail in Cavallo 1991).

The mental model test scores revealed the number and kinds of interrelationships students made in their explanations. For example, students' scores on the meiosis test reflected the extent to which they explained *how* meiosis occurs, *where* meiosis occurs, *why* meiosis occurs, and even *when* (under what conditions) meiosis occurs. Essentially, the scores represented the extent of students' meaningful understanding of the topics. The following student explanation is an example of a fairly meaningful explanation of meiosis:

> *Sperm cells are cells formed by meiosis inside the male. A cell doubles its chromosomes, the cell splits into two new cells. The two new cells then divide, splitting all pairs of chromosomes. When the process is complete there are four specialized cells with half the number of chromosomes as a normal body cell. The same process occurs in females, but only one of the four eggs can be fertilized.*

The student made several connections in the above explanation. The student recognized that cells are inside the male body, for example. The student also recognized that the end result of meiosis is four specialized cells with half the chromosome number and related this result with a normal body cell. The student did not explain, however, how the results of meiosis relate with or are important for fertilization (i.e. why the chromosome number is reduced to half the normal body cell number). Statements such as these would have indicated an even more meaningful understanding of meiosis and thus, a higher test score.

In addition to explanations like that presented in the first paragraph of this paper (i.e. naming the phases), the following is an example of a fairly rote explanation of meiosis:

> *Meiosis is cell reproduction. Gametes are egg and sperm. In meiosis, chromosomes duplicate. Meiosis is splitting of cells. Chromosomes split. Chromosomes carry genes and are in cells. Meiosis includes interphase, prophase.*

The focus of this student's explanation was on naming the objects (cells, gametes, egg, sperm, chromosomes, genes) involved in meiosis. There is little indication of how meiosis occurs and where it occurs (cells were mentioned, but there was no connection made between cells and a male or female body). There is no mention of the end results of meiosis nor of why meiosis occurs.

Data analyses (t-tests) were conducted to explore possible differences in mental model scores between males and females. The results of all mental model tests (students' explanations of meiosis, Punnett square diagrams, and the procedural and conceptual relationships between meiosis and the use of Punnett square diagrams in genetics) indicated no differences in meaningful understanding between males and females. The results of the t-tests were as follows: for meiosis, $t = -.749$, df = 138, $p = .458$; for Punnett square diagrams, $t = -.631$, df = 138, $p = .529$; for the procedural relationships (i.e. how the two topics operate or work in relation to each other), $t = 1.46$, $df = 138$, $p = .146$; and for the conceptual relationships (i.e. the logic of why these two topics are related), $t = .745$, $df = 138$, $p = .457$. In other words, males and females performed equally well on all of the open-ended essays. (Scores on a test measuring students' written expression ability showed no differences between males and females).

The state biology examination tested these students' knowledge of the various topics taught throughout the course. The results were contrary to those found with the open-ended tests. On the multiple-choice biology examination, the males' performance was significantly higher than the females' performance ($t = 2.07$, $df = 134$, $p < .05$). The mean score (out of 100%) achieved by male students was 78; the mean score for the females was 73.

Science Is for Everyone

Do females memorize science more than males? Are females less well-prepared or less able in science than males? The teachers perceived the females as learning more by rote than the males, but gender differences were not evident when students conveyed how they approach learning themselves. The multiple-choice test indicated lower biology achievement among females than males. Yet, when students were given the opportunity to fully express what they knew about selected biology topics, there were no apparent differences in achievement between females and males.

Because the mental model tests were not given on all biology topics (for practical reasons) these results should be interpreted with caution. Further attention and research are needed in this area in order to clarify these findings. Nonetheless, the findings raise awareness and point to certain issues that science educators should consider.

First, it appears that females may not learn biological topics by rote or by meaningful learning any more than do males. Science educators need to be certain that opinions about, and especially actions toward, all students are fair and accurate. Although the teachers of this study were experienced, gender bias may be a factor associated with their instruction. Gender bias was found among teachers in a study by Shepardson and Pizzini (1992) in which teachers rated their male students as having greater "cognitive intellect" for science as compared to their female students. The authors concluded that, "Teachers' perception of the scientific ability of students may result in differential treatment of girls, which contributes to the discrepancy in the development of the scientific ability of girls and boys" (Shepardson & Pizzini 1992, p. 151). Do teachers treat female students differently because they are thought to memorize facts rather than understand information and experiences in biology class? Do teachers expect different learning behaviors and cognitive intellect from females and males in learning biological topics? These questions need to be carefully considered by science educators and may serve as a foundation for future research.

Secondly, in measuring students' accomplishments educators must ensure they are assessing what students truly know and understand, and not their ability to successfully take (or decode) a certain kind of test. Test questions may reflect the often inadvertent gender biases of the test writer (Linn & Hyde 1989; Sudweeks & Tolman 1993). A variety of techniques need to be used to measure students' understandings, including open-ended questions. With open-ended questions such as those used in this study, students' expressions of what they know are not restricted by a list of pre-written questions. Knowledge and understanding may be revealed in students' explanations that may not be "tapped" by forced-choice questions. Educators should consider providing more opportunities for students to express (or demonstrate) their understandings of science. In doing so, one may be surprised to uncover quite complex, insightful and meaningful understandings among students that may have otherwise gone unrecognized.

Finally, emphasizing memorization of textbook definitions and facts is an outdated, ineffective teaching practice, and is contrary to the very nature of science. Science is not a list of terms and definitions to be memorized; it is a dynamic, ever-changing domain of discovery and exploration. Educators need to help students view science as a continuous process of exploration and help them build understandings of the world. To assist this effort, teachers need to use strategies that will help all students use more meaningful learning approaches (see Novak & Gowin 1984). Students are likely unaware of their own learning approaches and need to think about their own thinking (see Novak & Gowin 1984). The use of metacognitive strategies and meaningful learning strategies, such as Vee diagrams and concept mapping, may help students better understand their own learning styles. Such strategies may also help teachers become more cognizant of their students' learning patterns and help teachers devise more meaningful instruction.

Educators need to view science as being for *all* students. Male and female students alike should be challenged to think at high levels, to solve problems, and to create new solutions and ideas in science. It is important that all students learn to make sense of what they encounter in the natural world. Educators must continue efforts toward helping all students meaningfully learn and understand how biology is relevant to their lives.

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