leges of the University and by numerous other institutions.

The Illinois Course Evaluation Questionnaire (CEQ) is based on the premise that for a course to be effective it must have a large number of elements contributing to this effectiveness, such as the instructor, textbook, homework, course content, method of instruction, student interest, student attention, general student attitude towards the course, etc. Assuming that all of these elements can affect, directly or indirectly, student behavior in a course, and assuming that the students are the only ones who are constantly exposed to those elements, then the students appear to be the most logical evaluators of the quality and effectiveness of the course elements. In addition, student opinions should indicate areas of rapport, degrees of communication, or the existence of problems that describe and define the learning environment more concretely and objectively than other types of measurements.[2]

The instructor is only capable of influencing the learning situation to the degree that he is not restricted by elements outside of his control. Some of these outside elements would include scheduling, grouping, course content, curriculum or college requirements, and previous student opinions. It is possible that an instructor might teach certain content well, but opinions about his teaching effectiveness could be prejudiced by the attitudes toward the content of the course *per se*. Therefore, the Illinois Course Evaluation Questionnaire (CEQ) was developed to test these elements separately.

The following criteria were established for the CEQ and, based upon our experience, appear to have been successfully met:

1. Administration: The questionnaire can be administered by the instructor himself during regular class periods. Descriptive data can be collected by placing appropriate questions on the back of the one-page 8½ x 11 questionnaire. In order to get unbiased answers it is best to have a co-worker administer the questionnaire and let the responding students know that the instructor will not see the replies until after final grades are given, and then, only as compiled statements or averages without any association with a student's name.

2. Time: It normally takes 15 minutes for a student to complete the questionnaire, somewhat longer if descriptive statements are requested. This is short enough to be acceptable to faculty in regular classes, but long enough to insure reliability and adequate measure of a wide sample of attitudes.

3. Content: Out of a pool of 1,000 items the content of the questionnaire was reduced to 50 items, which includes 22 negatively stated items that provide a check on careless student responses.

4. Scoring: Copies of the questionnaire are printed on a Digitek Answer Sheet. Each student responds by marking directly on his own answer sheet with a conventional graphic pencil. On each of the 50 items he indicates his agreement or disagreement on the 4-point scale: strongly agree (SA), agree (A), disagree (D), and strongly disagree (SD). Tabulation is completed by machine so the results can be determined promptly and accurately.

5. Reliability: The correlation between 22 negative and 22 positive items for a sample of 297 CEQ's was .849. A split-half reliability was computed with half the negative and half the positive items in each group; thus 25 items in each half. The result for the sample of 297 was .93. In addition, the Kuder-Richardson reliability formula 21 was computed separately for 16 different courses and averaged .91.[3]

6. Interpretation: Six subscales were developed by factor analyzing the CEQ's 50 items which appear to cover the basic course elements. The subscales are labeled as follows: (a) General Course Attitude, (b) Method of Instruction, (c) Course Content, (d) Interest and Attention, (e) Instructor, and (f) Other. Each of the subscales contains 8 unique items except for Other which contains 10 items. Based on the face validity of the CEQ and its high reliability, extremely low scores on a particular subscale should indicate "felt" problem areas in an instructor's teaching procedure. Stable high scores should point to an effective instructional program as viewed by students. All evidence to date, from more than 100,000 students and 400 different courses, indicates that the CEQ does indeed identify courses that are considered to be very good or very bad. Results for interpretation are received as a computer print-out which indicates each of the 50 specific item responses, their means and the norm decile. The print-out also indicates subscale total scores, means and norm decile. Normative date, expressed in deciles, is based upon the responses of the total normative population (all student responses). The normative data for the subscales is also reported by other breakdowns which can include comparisons with other instructors of similar rank, others teaching a similar course level in the department, college or total university, as well as an all-university comparison.

The CEQ is not a complete diagnostic tool of teaching or instruction – no instrument can be. There are too many specific variables in a learning environment which can be scrutinized to measure or evaluate them all on a questionnaire, and some would be valuable in one setting and not in another.

The Research on student opinion questionnaires in general would seem to indicate that there is some reasonable relationship between teaching effectiveness and student judgments of this effectiveness. However, it is far from perfect; and for some questionnaires, the relationship appears nonexistent. Users of the CEQ are advised that: (1) The questionnaire collects some opinions only, it does not sample all opinions that may exist about a course, and (2) the opinions that develop about a course are developed through a variety of causes and not because of the instructor alone. It is recommended that the results of one semester sample be treated quite tentatively until validated by measures over two or more semesters.

Fourteen different universities and colleges have used the CEQ with satisfactory results. Details on how your institution might use the CEQ can be obtained from Measurement and Research Division, Office of Instructional Resources, University of Illinois, 307 Engineering Hall, Urbana, Ill. 61801.

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3. Spencer, Richard E. and Aleamoni, Lawrence M., "A Student Course Evaluation Questionnaire," Journal of Educational Measurement (Vol. VII, No. 3, Fall, 1970) pp. 209-210.

Teaching the Concept of Biological Variation in Introductory Life Science Courses[1]

Elmer Gray[2]

In introductory life science courses, students are informed that living organisms have certain characteristics. Variation is not usually included as one of these characteristics, but perhaps should be.

Evidence of biological variation is omnipresent. Variation is the basis on which living organisms are divided into taxonomic groups such as kingdoms, classes, genera, etc. Variation is present within the smallest taxonomic unit. In cross-fertilizing populations variation tends to be high. Even for populations of organisms which reproduce through self-fertilization or asexually, one could ask the question, are there any two living organisms that are identical?

The significance of biological variation is almost incomprehensible. Without variation the situation would be monotonous. Since there would be no variability on which selection could operate, there would be no possibility of evolution. The importance of variation in domesticated animals and plants has been well established. Species and strains within species differ in many characteristics including such important traits as adaptability and productivity.

The purpose of this treatise is to develop a method of teaching the concept of biological variation in introductory life science courses. The degree of expression of a characteristic in an organism is controlled by the organism's genetic makeup and its environment. Variability in phenotypic expression of a characteristic among genetically different organisms when grown in different environments is determined by genetics, environment, and genetics X environment interactions. These components are equated with phenotypic variation as follows:

$$\text{variation in phenotype} = \text{variation due to genetics} + \text{variation due to environment} + \text{variation due to genetics by environment interaction}$$

Phenotypic Variation

Phenotypic variation or variance is the total biological variation in expression of a given morphological, physiological, or behavorial characteristic. These characteristics include: weight, height, protein content, number of leaves, color of eyes, pigmentation, reactions to adversity, etc. For convenience of discussion, phenotypic variation is divided into two types – discontinuous and continuous.

When the variability for a given character is discontinuous, such characters are described as being qualitative. For a given qualitative character individual organisms fall into distinct classes with little or no connection by intermediates (Fig. 1). Expression of qualitative characters is controlled by relatively few genes which segregate into Mendelian ratios. Examples of qualitative characteristics include: some types of disease resistance, ability to synthesize certain chemicals, dwarfness, awnlessness, aleurone color, certain chlorophyll deficiencies, blood groups, coat color patterns in animals, and nodulation in soybeans.

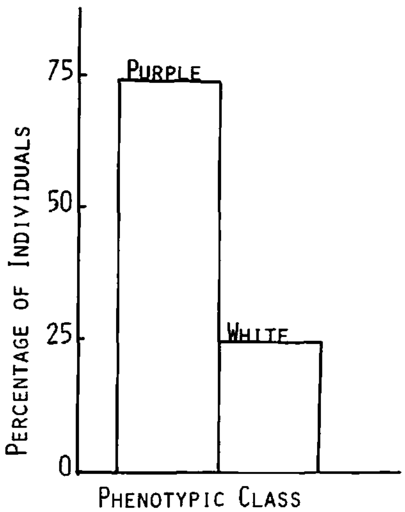

Figure 1. Frequency distribution of a qualitative character. F_2 segregation of purple and white aleurone colors in corn.

If the variability in expression of a character is continuous, the character is said to be quantitative. Individuals do not fall into discrete classes for quantitative characters because there may be all degrees of expression within the range of phenotypic variation (Fig. 2). Quantitative characters are controlled by many genes where each gene has a small effect and expression of the genes may be strongly influenced by the environment. Most of the more economically important characteristics of plants and animals are quantitative. Some of these include: production, adaptation, weight, height, and intelligence.

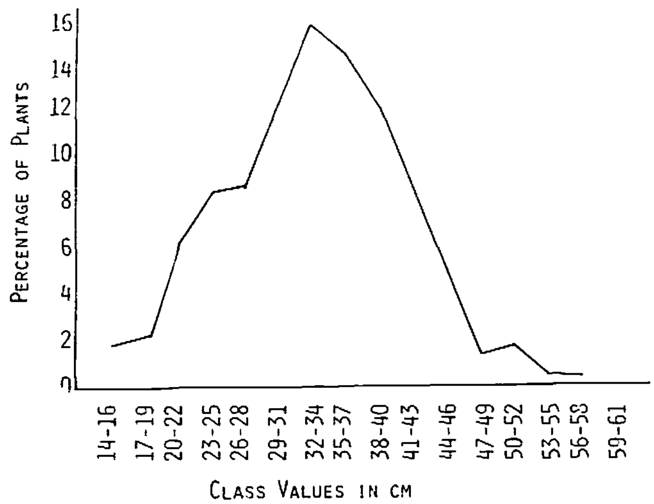

Figure 2. Frequency distribution of a quantitative character. Height of 411 three-week old corn plants.

Genetic Effect

The genetic component of phenotypic variation includes all types of changes in genes, chromosomes, or other hereditary materials which have an effect on the genotype of the organism. The genetic effect can be demonstrated by growing genetically different organisms in a uniform environment (Fig. 3).

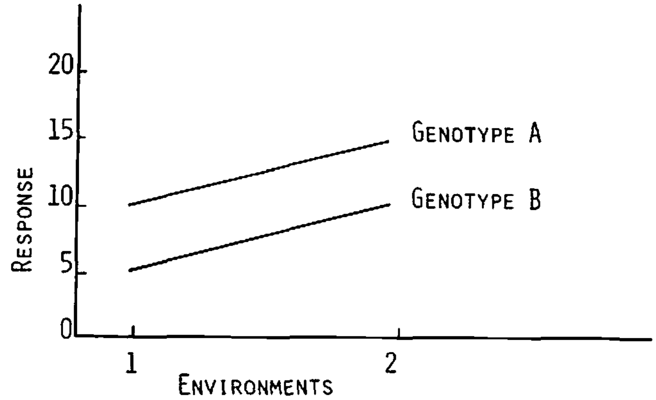

Figure 3. Hypothetical example of responses which show evidence of a genetic effect – genotype A is superior to genotype B in both environments, and evidence of an environmental effect – both genotypes performed better in environment 2 than in environment 1. There is no statistical evidence of a genotype X environment interaction.

The proportion of the phenotypic variation that is attributable to the genetic effect may vary from near zero to near 100 percent depending upon the character. For qualitative characters most of the variation in phenotype is due to the genetic component. Estimates of the amount of phenotypic variation attributable to genetics for quantitative characters vary widely, depending upon the complexity of the character.

Only the genetic component of phenotypic variation is transmitted from generation to generation; therefore, effective selection, either natural or artificial, depends upon the genetic contribution to variation. Other factors being equal, the effectiveness of selection increases as the proportion of the phenotypic variation attributable to genetics increases.

Environmental Effect

The environmental effect includes all non-genetic factors which influence phenotypic expression of a trait. The most common environmental factors which influence phenotypic expression are either climatic (light, water, oxygen, heat, carbon dioxide, etc.) or nutritional (minerals, vitamins, energy, etc.). The environmental effect can be observed by subjecting genetically uniform organisms – identical twins, asexual offspring of a single organism, individuals from pure lines, or F_1 hybrids between pure lines – to different environments (Fig. 3).

Some kind of environment is essential for the expression of any character; however, the degree of expression of qualitative characters is usually not greatly influenced by the environment. The environmental component may account for varying amounts of the phenotypic variability in quantitative characters. The environment may cause a major portion of the variability in more complex quantitative characters, or only a minor portion in less complex characters.

The environmental component of variation is of concern to the physiologist, ecologist, and nutritionist as they strive to increase phenotypic expression of desirable plant and animal traits by finding or creating favorable environmental conditions. Sometimes improvement in phenotypic expression of a character is accomplished through the control or elimination of an adverse factor in the environment. For example, a pathogen could be controlled or a toxic element could be inactivated or removed from the environment.

Genotype by Environment Interaction[3]

A genotype X environment interaction effect is evident when two or more genotypes fail to respond the same, relative to one another, when grown in two or more environments. Two genotypes may differ in their response to a given environment, thereby indicating a genetic effect (Fig. 3). The response of two genotypes may change when grown in different environments indicating an environmental effect (Fig. 3); but, if the change is the same for each genotype, then there is no statistical evidence of a genotype X environment interaction (Fig. 3).

When there was no interaction (Fig. 3), the lines connecting genotype response levels between the two environments were parallel; whereas, when there were interactions (Fig. 4 and 5) the lines were not parallel. Statistical evidence of interaction can be detected by plotting responses in this manner and determining whether the lines diverge or are parallel. Statistical analyses are required to determine whether deviation from parallelism is likely to be real or due to chance.

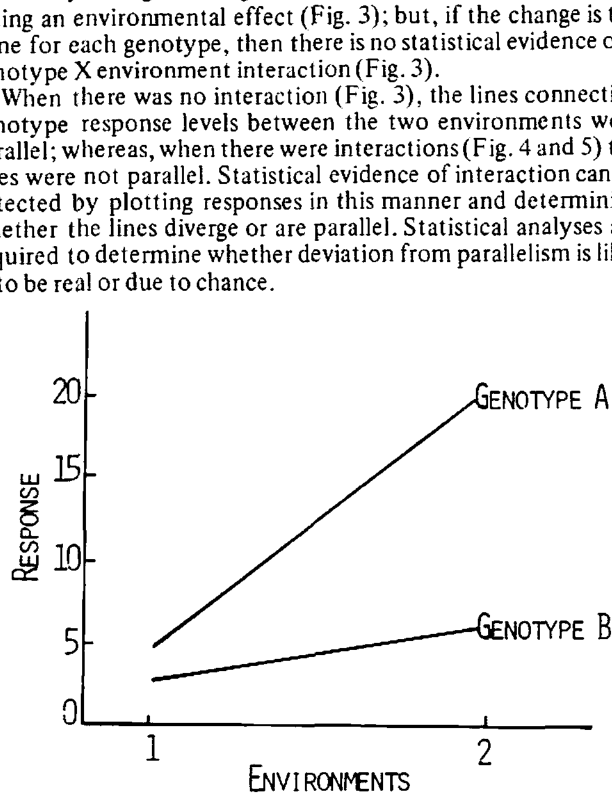

Figure 4. Hypothetical example of responses which show evidence of a change-in-rate interaction. Some factor(s) in environment 2 permitted a greater increase in response of genotype A than in genotype B.

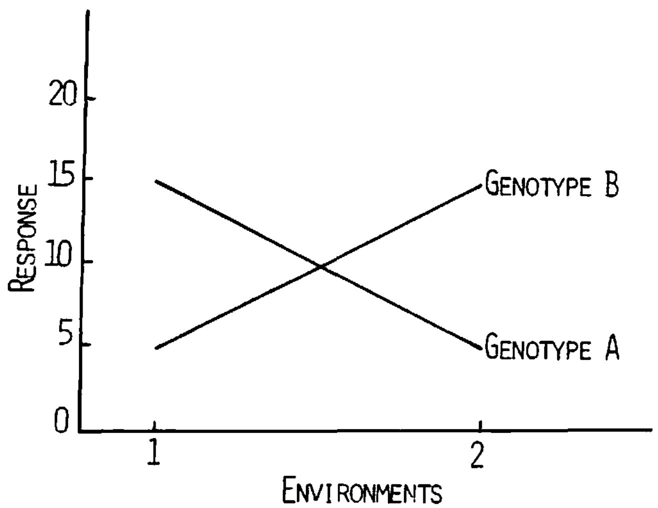

Figure 5. Hypothetical example of responses which show evidence of a complete reversal interaction. Genotype A was superior to genotype B in environment 1, but A was inferior to B in environment 2.

When the response lines are parallel, the difference (d_1) between the response of the two genotypes in environment 1 is equal to the difference (d_2) between their response in environment 2. Interaction is the difference (d_i) between d_1 and d_2. When response lines are parallel, $d_i = d_1 - d_2 = 0$, and there is no interaction. In both the change-in-rate and complete reversal interactions, d_1 and d_2 are not equal and a numerical estimate of d_i can be calculated.

What causes genotype X environment interactions? At the basic level, genotype X environment interactions involve developmental pathways by which final characters are reached. The intricate sequences between the genetic code and the final character in highly developed organisms provide many chances for the environment to alter the developmental process. This pattern of alteration would rarely be the same in different genotypes when grown in different environments; therefore, genotype X environment interactions would occur.

Genetic X non-genetic interactions largely reflect the activity of certain genetic materials in one environment and the reduced activity or total inactivity of these genetic materials in another environment. Suppose that genotypes A and B have genetic potentials for 70 and 100 units of production, respectively. If these genotypes are grown in environment 1 which will support only 80 units and environment 2 which will support 110 units of production, this situation would result in a change-in-rate interaction. The genes for greater production in genotype B could only be partially expressed in environment 1, but could be fully expressed in environment 2. For another example, suppose that genotype A has greater genetic potential for yield than B and that A is susceptible to a damaging disease to which B is resistant. If these two genotypes are compared in environment 1 which is favorable for growth and is free of this specific disease, A should yield better than B. However, when compared in environment 2 which is similar, except that the disease is present, B could yield better than A. This situation would result in a complete reversal interaction. The effect of B's genes for resistance was of no value in environment 1 where the disease was absent. The effect of A's genes for greater yield were not expressed in environment 2 because the disease limited its yield.

Examples of Effects of the Components of Variation

Evidence of the influence of genetic, environmental, and genetic X environmental interaction effects on phenotypic expression is abundant in studies comparing genotypes (genera, species, subspecies, etc.) of plants or animals when subjected to different environmental conditions (rations, temperatures, populations, moisture conditions, etc.). Three examples will be given:

Example 1 (Graves, 1962). The following figures are leaf yields (kg/ha) of three burley tobacco cultivars when grown at two locations in Tennessee.

	Location		
Cultivar	Greeneville	Springfield	Average
Ky. 10	2620	2124	2372
Ky. 12	2326	2182	2254
Burley 1	2375	1865	2120
Average	2440	2057	

Evidence of the genetic effect on yield is apparant from the differences among cultivars within a location and from the differences among average cultivar yields across locations. The differences between location yields for a given cultivar and the difference between location average yields are evidence of the environmental effect on yield. Yield of Ky. 10 exceeded that of Burley 1 at Greeneville by 245 kg/ha (d_1), and yield of Ky. 10 exceeded that of Burley 1 at Springfield by 259 kg/ha (d_2). The estimated interaction ($d_i = d_1 - d_2 = 245 - 259 = -14$) is near zero; therefore there was little or no evidence of an interaction between Ky. 10 and Burley 1 at these locations. Yield of Ky. 10 exceeded that of Ky. 12 at Greeneville by 294 kg/ha (d_1), and yield of Ky. 10 was 58 kg/ha less than that of Ky. 12 at Springfield. The estimated interaction was 352 (294 - (-)58) indicating evidence of an interaction between Ky. 10 and Ky. 12 at these locations.

Example 2 (Brewbaker, 1964). The complete reversal interaction is illustrated by changes in acidity of two cultivars of oranges when grown at different elevations in Hawaii.

	Elevation	
Cultivar	152 m	305 m
Washington Navel	high	low
Satsuma Mandarin	low	high

Example 3 (Falconer, 1960). The complete reversal interaction is demonstrated in animals by the amount of gain by two strains of mice on two levels of nutrition.

	Level of nutrition	
Strain	Good	Poor
A	17.2g	12.6g
B	16.6g	13.3g

Strain A made more gain than strain B under good nutrition, but A made less gain than B under poor nutrition.

Discussion

Students need an understanding of biological variation early in their study of biology (including related areas). An appreciation of the roles of heredity and environment in determining phenotypic variability should better prepare them for courses relating to environment (ecology, nutrition, pathology, etc.) and for courses relating to heredity (genetics, breeding, etc.). For example, an understanding of variation is essential before the concept of selection can be discussed meaningfully. Selection, which is the sorting of types, may occur only when there is phenotypic variation. If the variation is due entirely to the environmental effect, propagation of selected types would not change the population, because only the genetic effect is transmitted from generation to generation.

Research programs, which have as their objective the improvement of performance of domesticated animals and plants, focus both on the organism's environment and its genetic constitution. Maximum performance is obtained by having the best genotype in its most suitable environment.

Student understanding of genotype X environment interactions and their implications to biologists is of great importance. Species and breeds of animals differ in their response to nutritional and climatic conditions. Species and cultivars of plants differ in their reaction to soils, climatic conditions, and management practices. A given producer may need to grow several cultivars of a species in order to meet the production and utilization demands placed upon that crop.

Genotype X environment interactions are involved in courses concerning evolution of plants and animals. When a given genotype fits a particular niche in the environment better than other genotypes, it may develop into an ecotype and possibly into a new species.

Helping the student enhance his understanding of the great diversity of environments, the vast variability in genotypes, and the complexity of genotype X environment interactions is a challenge to teachers of life science courses.

Summary

Biological variation is omnipresent. Phenotypic variation in populations of organisms subjected to different environments reflects variation due to genetics, environment, and genetics X environmental interaction. The genetic effect may be demonstrated by comparing genetically different organisms in a uniform environment. The environmental effect may be observed by exposing organisms with identical genotypes to different environments. Genetic X environmental interactions are evident when two or more genotypes fail to respond the same, relative to each other, when subjected to two or more environments.

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[2] Professor

[3] Genotype X environment interactions are discussed from a statistical view point; differential performance of genotypes in different environments is considered necessary in order to have a genotype X environment interaction. This is a more restricted interpretation of genotype X environment interactions than that proposed by Haldane (1946) and discussed by Allard and Bradshaw (1964).

If the relative response of genotypes A and B differs in environment 1 and 2, then there is evidence of a genotype X environment interaction. For example, A may have been only slightly superior to B in environment 1, but A may have been greatly superior to B in environment 2 (Fig. 4). Such a response is referred to as a change-in-rate interaction. If the response of genotype A is greater than that of genotype B in environment 1, but the response of genotype A is less than that of genotype B in environment 2, such a relationship is referred to as a complete reversal interaction (Fig. 5).

Statements of Teaching Philosophy from nominees for the Ensminger-Interstate Outstanding Teacher Award.

A STATEMENT ON MY TEACHING PHILOSOPHY

JAMES L. AHLRICHS

To teach is to help students learn. Teaching must be student-centered. We do teach persons, although we often say we teach "our subject." My philosophy says that a successful teacher needs to combine empathy for the student with teaching skills and with an active personal involvement in the subject matter being taught.

Student-centered teaching means a student-centered working day. The office must be near to the classroom and the door must always be open. Closed doors intimidate students. My actions must always say "Students, please interrupt; my guests and my work will excuse us."

Student-centered teaching requires that each student have a clear understanding of what he is expected to learn. Thus, my teaching now always provides students with "objectives" by natural units or by weekly intervals. These enumerate what I expect them to learn (to be able to do, to list, to explain, to reproduce, to use, etc.).

Student-centered teaching requires that the material to be learned be available when the student is best able to study, for as long as he wishes to study and for as much repetition as he needs. Modern technology helps to provide this. A "study center" open many hours per week; personal cassette tapes of directive comments, personal copies (by ditto or photocopy) of figures and other "blackboard" material, and units of work (experiments and demonstrations) set up for a week or longer all represent the type of approach which will help to free students from the rigid limitations of time and space schedules.

Using technology to do some of the routine and add to flexibility of teaching also frees me, the teacher, to be a tutor of individuals in the study center or in small discussion sessions rather than a lecturer to large groups. This helps accommodate the diverse backgrounds of students. It also enables personal discussion of the relevance of specific subject matter to the professional or academic interests of the individual.

One's teaching and academic professions must be nurtured and stimulated continually. I do this faithfully reading two professional education journals and by regularly participating in or directing teaching seminars. This improves my understanding of teaching as a profession and as a skill.

Active participation in laboratory research with two graduate students, participation in a weekly research seminar and occasionally assisting colleagues with field research keeps me highly involved and motivated in my subject matter specialty.

Helping others learn is a great and rewarding way of putting my knowledge and experience to meaningful use.