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Introduction

Have we, as educators, reached a point in our society where "Truth in Learning" has become as important as "Truth in Lending"? We have seen government agencies mandate controls over banks, as well as auto-mechanics, to become more accountable for their services. Now, it seems that these same controls are to be levied on those in the educational systems of this nation as well.

For too many years, educators have had the attitude that some information must be kept hidden from the student--or the "don't tell them or they will know everything" syndrome. Course titles do not always indicate what the course concerns. Often advanced courses are nothing more than mere reruns of a lower level course, which may or may not have the same title.

Students are now beginning to demand their rights by voicing their discontent, even to the courts of the land. No longer do they stand idly by and accept that which is sometimes even slovenly given. Students are demanding the education for which they have paid and are not remiss in charging the institution, department, or even the individual teacher to become accountable for their actions.

This manuscript centers about two introductory, majors courses in biology at Ball State University--Principles of Biology I *and* II. Nevertheless, it is hoped that many of these remarks will be equally applicable to, or provide some ideas for, any course which one might wish to make educationally accountable.

What is meant by accountability? According to a recent article in *Science Education* "...the key to accountability is student performance."[2] This statement provides an operational definition that can be measured.

Ball State University is on the quarter system, and usually there are ten to twelve sections in Biology I and from six to ten sections in Biology II. Each section of both courses normally has a maximum of twenty-four students;

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thus, the total number of students ranges from 400 to 525 per quarter. All sections are taught by regular faculty or by advanced doctoral students, who also teach the accompanying laboratory. The schedule followed by students in these courses is composed of three, 50-minute, lecture-discussion periods and one two-hour laboratory period per week. The senior author serves as coordinator of these two courses.

Measuring Accountability

Students are provided at the beginning of the quarter with a calendar of topics, reading assignments and laboratory assignments for the entire quarter. A weekly staff meeting is held for all teaching faculty in these courses to discuss effective teaching strategies for the topics under discussion, to facilitate and coordinate these topics with laboratories and to discuss appropriate and available teaching aids.

The goals of these two courses were defined by the teaching staff in Biology I and II using the expertise of faculty who had been teaching beginning biology courses for majors. These goals were based upon an assessment of student needs. Using the identified goals, topics as listed in Table 1 were developed and assigned to these courses. Performance objectives were then defined and written for each of the topics. Since these two biology courses provide the basis for the remainder of our core sequence, a major aim in writing these objectives was to make certain that the topics would be taught at a concept or principles level. Students are provided with a complete list of these performance objectives either at the beginning of the course or at the beginning of each topic, depending upon the discretion of the instructor.

Table 1

TOPICS COVERED IN
PRINCIPLES OF BIOLOGY I & II

BIOLOGY 111	BIOLOGY 112
DATA INTERPRETATION & BIOSTATISTICS	MEIOSIS AND SEXUAL REPRODUCTION
BIOINSTRUMENTATION & THE TOOLS OF SCIENCE	GENETICS
DIVERSITY OF LIFE	PROTEIN SYNTHESIS & GENES IN ACTION
CELLULAR MACHINERY	PLANT & ANIMAL DEVELOPMENT
MOLECULAR MACHINERY	CELLULAR REGULATION & CONTROL
ENERGY FLOW (THERMODYNAMICS & ENZYMES)	EVIDENCE FOR AND MECHANISM OF EVOLUTION
PHOTOSYNTHESIS	PRINCIPLES OF ECOLOGY
CELLULAR RESPIRATION	
DNA AND CHROMOSOMES	
MITOSIS AND ASEXUAL REPRODUCTION	

Performance objectives serve a dual purpose: (a) to provide the teaching staff with a guide to the depth and type of coverage for each topic, and (b) to provide the student with a sequence of faculty expectations. For example, students are told that the exams will cover specific objectives rather than a certain number of chapters. This helps students to focus their attention on the important concepts and directs their study towards behavioral patterns which are expected of them.

Staff members have collectively written questions to be used on a pre/posttest based on the objectives developed for each topic. The staff collectively establishes face validity for each test item by matching the item with the behavior required in the performance objective. Test items are constantly being revised as a result of analyzed data obtained from computer output on test results and item analysis.

Before presenting examples of these objectives with their corresponding test items, it is important to note that the staff truly believes that these objectives represent the behavior to be learned in these courses; therefore, if students meet a level on the pretest that is ordinarily attained by the average student at the end of the course, they are allowed "*credit by examination*" and move on to the next course in the core sequence. The actual score at which "*credit by examination*" is allowed on the pretest is obtained by calculating the mean posttest score for each final grade assigned in the course in previous quarters. The score at which students are allowed "*credit by examination*" is based at approximately the posttest score received by students in the high "C" range. Students receiving a pretest score at this level are then individually counseled to move on, or to stay in, the course depending on such factors as: their confidence in trying the next level course; how important this course is to their stated major; whether or not they have had other biology or biology-related courses either in college or high school.

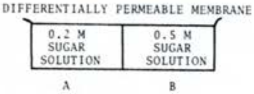
Figures 1 and 2 show examples of sample instructional objectives with their corresponding test item. The pre/posttest consists of fifty test items. The student answers these test items by marking an *Alpha Answer Sheet*. This answer sheet can then be computer graded both for a total score correct (50 possible) and for a subscore on each major topic. The staff is also furnished with a complete test analysis based on a norm-referenced program supplied by the University Testing Service of Indiana State University. The test is actually a criterion-referenced test, and this is kept in mind in interpretation of the computer output; however, much information can be gained from such a norm-referenced analysis.

The *Alpha Answer Sheet* codes each student in each section by name and social security number. It also provides a read-out from the computer which lists students alphabetically. Since each student has used this answer sheet, the instructors will receive information, as shown in Figure 3, for each of their sections. Only a portion of a section is shown in Figure 3 and names and social security numbers are fictitious.

SAMPLE INSTRUCTIONAL OBJECTIVE:

GIVEN THE CONCENTRATION OF SOLUTIONS SEPARATED BY A DIFFERENTIALLY PERMEABLE MEMBRANE, PREDICT THE FINAL CONDITION OF THE SYSTEM.

CORRESPONDING TEST ITEM:



IN THE EXAMPLE ILLUSTRATED ABOVE, AFTER A PERIOD OF TIME THE LEVEL OF WATER IN THE BEAKER WOULD INDICATE WHICH OF THE FOLLOWING HAD OCCURRED?

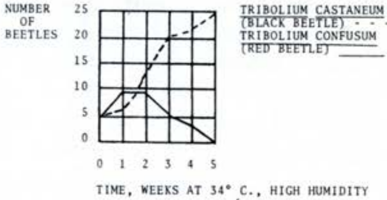
A. EQUAL MOVEMENT IN BOTH DIRECTIONS
B. GREATER NET MOVEMENT FROM A TO B
C. GREATER NET MOVEMENT FROM B TO A
D. NO MOVEMENT
E. NONE OF THE ABOVE

Fig. 1.

SAMPLE INSTRUCTIONAL OBJECTIVE:

ANALYZE THE RESULTS OF A BIOLOGICAL EXPERIMENT THAT HAS BEEN EXPRESSED GRAPHICALLY.

CORRESPONDING TEST ITEM:



TWO SPECIES (SHOWN ABOVE) OF TRIBOLIUM BEETLES WERE CULTURED IN THE SAME BOTTLE. THE BEST CONCLUSION WHICH CAN BE DRAWN FROM THE ABOVE GRAPH IS THAT:

A. RED AND BLACK BEETLES CAN LIVE TOGETHER AT 34° C AND HIGH HUMIDITY
B. RED BEETLES CANNOT SURVIVE AT 34° C AND HIGH HUMIDITY
C. THE RED BEETLES REPRODUCED FASTER THAN BLACK BEETLES UNDER THESE CONDITIONS
D. BLACK BEETLES ARE STRONGER THAN RED BEETLES
E. BLACK BEETLES COMPETE MORE SUCCESSFULLY THAN RED BEETLES AT 34° C AND HIGH HUMIDITY

Fig. 2.

BSU EXAM SERVICE BIOLOGY 111 – ALLAMONG SECTION 1

ID	Name	Number Right	Number Wrong	Number Omitted	Score
311603390	J. Brown	30	20	0	30
303687933	C. James	35	15	0	35
316526453	S. Robinson	21	29	0	21
313503825	J. Stanley	34	16	0	34
310663012	A. Yeager	34	16	0	34

Mean = 29.55 Standard Deviation = 5.43 Number = 22

Figure 3

Computer data provides combined information from all sections in determining the *Answer Distribution Analysis* as shown in Figure 4. Of the total number of students responding to each test item, the number responding to each choice is shown. The correct answer is indicated by an asterisk. Perusing this information provides a quick check on the difficulty of the item. Item No. 4 obviously was a much easier item than No. 3. It is inferred that the distractors were apparently more plausible in item No. 3. Analyzing this data provides a means of checking to see if the right answer is being scored. In one case when the wrong answer was inadvertently punched into the computer, it was immediately obvious when only a very small number of students answered the item beside the asterisk. A quick check of the test question confirmed what had happened.

ANSWER DISTRIBUTION ANALYSIS

Item	A/1	B/2	C/3	D/4	E/5	Omits
1	10	33	13	94*	19	0
2	36	73*	39	9	7	5
3	21	42	14	63*	28	1
4	2	2	112*	47	6	0
5	3	3	140*	10	12	1

*Asterisk indicates correct answer

Figure 4.

The *Examination Item Analysis*, Figure 5, shows a comparison of the same item on the pre/posttest. Five items were selected at random for comparison and the same item was compared on the pretest and the posttest. The items are compared as to item difficulty. (Difficulty is the percentage of students who answered the item correctly.) The difficulty score on the pretest indicates how many students have mastered a certain behavior. If all items on a given topic rank high in the "difficulty" area on the pretest, coverage of this topic might be lessened or simply reviewed briefly during the course. A comparison of the pretest and posttest "difficulty" will indicate how much population gain has been made on a particular item during the course. This same comparison also indicates how well the students' needs were met by our teaching methods. If it is clear that the gain has not been significant, the staff may ask certain questions, such as: "Should teaching methods be altered?" or "Is the test item inappropriate?" or "Is the level of difficulty too high?"

EXAMINATION ITEM ANALYSIS

	PRETEST		POSTTEST	
Item	Difficulty [a]	Discrimination [b]	Difficulty [a]	Discrimination [b]
1	43.09	0.40	66.27	0.51
2	30.32	0.20	59.17	0.56
3	31.91	0.22	44.97	0.53
4	18.09	0.30	46.75	0.51
5	54.26	0.44	78.70	0.49

[a] Difficulty is the percentage of students who answered the item correctly.

[b] Discrimination is the extent to which an item is answered correctly by the higher scoring students and answered incorrectly by the lower scoring students.

Figure 5

Discrimination is the extent to which an item is answered correctly by the higher scoring students and answered incorrectly by the lower scoring students. This is a quick cross-check of the validity of each test item and at the same time it provides data concerning the readability of the item.

The computer output also provides "*Summary Statistics*" (Fig. 6). Examining such information provides a quick comparison between sections. Pre/posttest results are shown for four randomly selected sections. The mean scores indicate how well each section did at the beginning of the course and how well each section performed in comparison with all other sections. The posttest mean indicates the same data at the conclusion of the course. One additional piece of data is provided on the "*Summary Statistics*". It is a one-factor analysis of variance, addressed to the question of whether all sections may be regarded as having equally high achievement. The F-value (Fig. 6) indicates that there is no significant difference (.01 level) between the sections. The F-value may be used to check on uniformity of student gain among sections. If the F-value is not significant, this indicates that one section has either performed exceptionally well or exceptionally poor as compared to the other sections. The staff can then ask "Why?" By seeking the answer to this question, instruction can be improved.

SUMMARY STATISTICS

	PRETEST			POSTTEST		
Section No.	**Mean**	**Variance**	**S.D.**	**Mean**	**Variance**	**S.D.**
1	14.88	18.90	4.35	29.55	29.50	5.43
2	15.88	16.78	4.10	26.18	46.90	6.85
3	16.48	6.86	2.62	27.00	43.75	6.61
4	15.79	37.18	6.10	24.42	48.81	6.99
Total *	15.55	20.89	4.57	27.84	43.58	6.60

F-value (based on 9 sections) = 2.68

**Based on 9 sections*

Figure 6 .

Conclusion

The authors wish to introduce a question for thought at this point. If the various sections of the course are coordinated--receiving as nearly as possible the same instruction, why does the variance increase? Shouldn't a very heterogenous student population be brought closer together if instruction has been uniform and guided by a specific set of objectives? The sections compared in Figure 5 indicate that variance increased. There are several possibilities for explaining this result, such as: (a) Instruction may be helpful to some students, but not to other students. (b) We may be reaching one type of student more effectively than another type of student. (c) A few students do not faithfully attend class, yet do take the posttest. Obviously, we need additional data before we can speculate as to the actual reason.

Figure 7 provides some pertinent norm-referenced information. At first glance, and based on a decrease in variance, it appears that we are reaching the upper 27% much more effectively than the remaining 73% if a decrease in variance is an indication of success in teaching. This is not necessarily the case. To be confident that this was actually so, we would need to be sure that the student populations represented (upper 27%, middle 46%, lower 27%) were the **same** students on both the pretest and the posttest.

SUMMARY STATISTICS

	PRETEST			POSTTEST		
	Mean	**Variance**	**S.D.**	**Mean**	**Variance**	**S.D.**
UPPER 27%	21.10	11.07	3.33	35.84	6.45	2.54
MIDDLE 46%	15.38	2.31	1.52	28.20	6.50	2.55
LOWER 27%	10.32	5.16	2.27	19.20	6.30	2.51

Figure 7.

Although our efforts and plans are not fully achieved, we feel that we have made significant advancement toward making the two introductory biology courses at Ball State University more accountable.

Citations and References

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[3]Popham, James W. Ed. *Criterion Referenced Measurement*. Educational Technology Publications, Englewood Cliffs, New Jersey. 108 pp. (1971).

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Chance favors the prepared mind.

Louis Pasteur