Using Think-Aloud Protocols to Compare Cognitive Levels of Students and Professors in College Classrooms

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Abstract

In Bloom's Taxonomy, higher-order thinking is defined as application, analysis, synthesis, and evaluation (Bloom et al., 1956). Since thinking at these levels is an indispensable skill in the learning process and in everyday life, offering students opportunities to practice higher-order thinking during class is necessary.

The Florida Taxonomy of Cognitive Behavior (FTCB), created by Webb (1968), and based upon Bloom's Taxonomy (1956), was used to measure the potential level of cognition professors evoked in students through their various classroom behaviors. Then, from those professors' classes, students were randomly selected to engage in a think-aloud protocol to determine their cognitive level of thought during class. Frequencies were examined between professors' cognitive level of classroom discourse and students' cognitive level of thoughts during class.

Professor's taught 43% of the time at the knowledge level of cognition. However, the most common type of thought displayed by students in class was "random or nonsense thoughts" (68%). The least frequently utilized cognitive levels by professors were application (7%), analysis (7%), synthesis (7%), and evaluation (6%). Students concentrated an average of 4.5% of their thoughts in class at the analysis level, less than 1% at the synthesis level, and an average of 1% at the evaluation level.

Professors need to be aware of cognitive levels of teaching in order to use teaching techniques that develop students' ability to think at higher cognitive levels. On the other hand, students should challenge themselves to "think" during class about applications of the classroom material to their everyday lives.

Introduction

The need to have students graduate with a demonstrated capacity to think at the higher levels of Bloom's Taxonomy is more urgent than ever (Newcomb, 1995). Recently, however, there is concern that college and university students are not learning to their full potential. According to Whittington and Bowman (1994), several major national reports expressed the view that undergraduate education in general is incoherent and ineffective. The apparent foundation for these accusations is failure on the part of educators to challenge students to think. However, using Bloom's Taxonomy (1956) as a basis for examining cognitive levels of thought, it is possible to study both professors and students to determine the validity or lack of validity of these assertions.

Theoretical Framework

Bloom's Taxonomy of the Cognitive Domain

Bloom's Taxonomy of Educational Objectives: Cognitive Domain provides a useful framework for documenting the various cognitive levels at which the brain operates. Bloom's (1956) six-step hierarchical system of thinking moves from the knowledge level, that emphasizes recalling subject matter, to the evaluation level, that entails making judgments (Table 1). Each level is reflected through cognitive activities. Given that learning is enhanced by increasing the percentage of cognitive activity occurring at the higher levels of Bloom's Taxonomy, this framework gives focus and direction to teachers who are looking to improve the quality of learning in their classrooms (Whittington and Bowman, 1994).

Table 1
A Synopsis of Bloom's Hierarchy of Thought

Cognitive Level	Definition	Activity
Knowledge	Recalling subject matter	List, define, label, and match
Comprehension	Learners know information that has been communicated, but cannot apply in other situations	Explain, rewrite, paraphrase, summarize, and give examples
Application	Learners apply information to different situations and learning tasks	Compute, demonstrate, use, predict, discover, and solve
Analysis	Learners separate data into its component parts; these parts are differentiated and related based on their relationship	Differentiate, discriminate, relate, diagram, and distinguish
Synthesis	Combines learned elements to create a new whole; working into pieces and elements, arranging so as to create new forms, patterns, or structures	Create, compose, produce, and develop
Evaluation	Entails making judgment on the value of materials and methods for given purposes	Justify, compare, contrast, evaluate, and interpret

Note. McCormick, D. (1998). Adapted from Bloom et al., (1956).

Think-aloud Protocols

During the 1950's, the cognitive revolution initiated a new era of thinking about thinking by addressing fundamental questions about the human mind and by creating perspectives and tools to pursue the answer to those questions. Think-aloud protocols, the verbal reports produced by subjects who expressed their thoughts while engaging in some activity, has been one of the tools that allowed psychologists to explore previously inaccessible domains of cognitive processing (Kucan and Beck, 1997). Newell and Simon (1972) analyzed think-aloud protocols, and demonstrated how the pieces presented orally completed the cognitive puzzle's vast and empty interior.

Verbal reports were long used as data for psychological research because they provided information as to "what is going on in the mind" (Bowen, 1994). Piaget validated the use of verbal reports when he used them to test hypotheses based on subjects' responses (Abraham and Renner, 1986). Psychologists and researchers have documented think-aloud protocols as a means for collecting verbal reports to analyze human thoughts.

Higher-order Thinking

Higher-order thinking is defined as application, analysis, synthesis and evaluation (Bloom et al., 1956). Thomas (1987) further defined higher-order thinking as the ability to think critically, make ethically and intellectually defensive decisions, and reason.
According to Thomas, a higher-order thinker asks questions that probe what is known, deducts possible outcomes of a particular situation using principles, and tests one's own line of thinking and reasoning. Higher-order thinking requires the use of basic thinking skills such as knowledge recall, comprehension, and application, but analysis, synthesis, and evaluation are its primary cognitive requirements (Bloom, 1964). Since information is only useful when it can be applied and used for solving problems and making predictions (Underbakke et al., 1993), higher order thinking provides a foundation for effectively dealing with information (Halpern, 1984).

However, compared with educated students of other nations, our students are falling behind academically (Sternberg, 1985) due to underdeveloped higher-order thinking skills. For U. S. students, performance on moderately complex and scientific tasks has not changed in almost a decade, and only a small number of students, merely 7 % of 17 year olds, demonstrate such higher-level skills (Center for Critical Thinking and Moral Critique, 1992).

Thus, a lack of correspondence exists between that which is needed to develop higher-order thinking, and that which is actually being offered to students. Lecture, the most commonly used instructional method in the university system, often only offers students the opportunity to develop higher-order thinking skills on their own (Whittington et al., 1997). Most students, though, do not have the background in thinking skills development or metacognitive analysis to develop their own thinking skills (Center for Critical Thinking and Moral Critique, 1992). Ericksen (1984) concluded that students learn what they find interesting and only remember what they understand.

Previous studies have stated that professors often concern themselves with the content of their lectures, but spend less time thinking about student performance and the cognitive level their instruction reached (Whittington and Newcomb, 1991). In reality, the necessary higher-order thinking skills needed by students can only be developed through a learning environment that consciously teaches thinking skills and provides opportunities for interaction (Thomas, 1987).

However, a study by Cano and Newcomb (1990) showed that 60% of teacher instructional methods focused on knowledge and comprehension; 20% on application and analysis; and another 20% on synthesis and evaluation. Whittington (1995), in a study of 30 professors from The Pennsylvania State University, found that nearly 80% of discourse in college classrooms was at lower cognitive levels.

Engaging Thinking in Classrooms

The outcome of a curriculum should be to engage students in thinking at higher cognitive levels (Whittington and Bowman, 1994). Cano and Newcomb (1990) recommended that "teachers of agriculture should further develop a curriculum which appropriately challenges students at all levels of cognition" (p. 75).

Not only will a cognitively challenging curriculum enhance cognitive thinking levels in students, but the way in which the curriculum is taught will make the difference (Whittington and Bowman, 1994). Underbakke, et al. (1993) suggested that the teacher is the most powerful control factor that influences students' development of higher order thinking skills. Cano and Martinez (1991) concluded that "agricultural educators [need] to challenge students to develop cognitive abilities and critical thinking skills at higher levels via the instruction they provide" (p. 28).

An earlier study of strategic teaching methods concurred with recent research which concluded that teachers should establish goals for their instruction, and should consider teaching topics which are meaningful, applicable, and useful in students' lives (Ogle, 1989). Ogle stressed the importance of feedback between students and teachers, and also suggested using application and integration activities following the lesson in order to promote a deeper understanding of the subject.

Purpose and Objectives

The purpose of this study was to assess and compare the cognitive levels of instruction among professors from the Pennsylvania Governor's School for the Agricultural Sciences (PGSAS), and the cognitive levels of thought among PGSAS scholars. Specifically, the research questions guiding this study were:

- At what level of cognition were professors actually teaching?
- At what level of cognition were students actually operating?
- What is the comparison between the cognitive level of the professors' classroom discourse and the level reached by the students in those classrooms?

Methods/Procedures

Professors

Population and Sample

The target population in this study was 16 professors from the PGSAS at The Pennsylvania State University. Four professors' classes were randomly selected for analysis.

Instrumentation

In 1968, Webb used Bloom's Taxonomy to create the FTCB to assess the cognitive level of classroom discourse (the formal speech or conversation delivered during class) professors use when they teach. The FTCB utilizes 55 observable behaviors indicative of the various cognitive levels identified by Bloom's Taxonomy. In the "knowledge" category, 17 observable behaviors are listed on the instrument; for "comprehension," 12 observable behaviors are listed; for "application," four observable behaviors are listed; for "analysis," 11 observable behaviors are listed; for "synthesis," nine observable behaviors are listed; and for "evaluation," two observable behaviors are listed.

Validity for this instrument was based upon its direct development from Bloom's Taxonomy and the support generally given to this hierarchy of cognitive behaviors. Reliability for this instrument was established by coding audiotapes of lectures and establishing Spearman Rho reliability coefficients. Inter-rater reliability was approximately $r = .97$. Intra-rater reliability between previous researchers and the researchers in this study was approximately $r = .96$.

Data Collection

Professors knew which day the researchers would be in class. While attending each professor's class, the researchers recorded the frequency of observable teacher behaviors in six-minute intervals. Examples of observable behaviors at each level of Bloom's hierarchy include: "defines meaning of a term" (knowledge level); "shows cause and effect relationship" (comprehension level); "applies previous learning to new situations" (application level); "shows interaction or relation of elements" (analysis level) "formulates hypothesis" (synthesis level); and "evaluates something from evidence" (evaluation level).

In order to collect data on each professor's background, teaching skills, and knowledge of cognitive levels of teaching, professors completed a questionnaire. Each professor was also videotaped during the lecture.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences. Frequency of behaviors observed across all cognitive levels was totaled. Then the frequency within each cognitive level was divided by the overall total to acquire percentages of classroom discourse at each cognitive level. Cross-tabulations, frequencies, and means were calculated.

Students

Population and Sample

The second target population for the study was 64 scholars who attended the PGSAS during the summer of 1998. The 64 scholars were previously randomly divided into four sections of 16 scholars each for the school's administrative purposes. The student researchers were members of section one. Therefore, for access to the students, section one was utilized.

Since there were a limited number of days in which the researchers could interview scholars immediately after class, the four days in which there was at least a one-hour block of time immediately following class were chosen. Four scholars were randomly drawn for each interview date, followed by two alternates for each date. None of the alternates were used.

Instrumentation

A questionnaire designed by the researchers provided insight into potential reactions of the scholar to being interviewed, classes previously taken that would give background in the material being taught, and information about the scholars' interests and reasons for attending PGSAS. Scholars completed the questionnaire prior to the interview.

Data Collection

To understand how students are responding to teachers who teach to higher cognitive levels, researchers used think-aloud protocols (verbalization of thought processes). In this study, subjects knew prior to class that they would be interviewed about their thoughts during class. The subjects were told the objectives of the study. Immediately following class, students were given a hand-held tape recorder and asked to watch the videotaped lecture, listen, and audibly recall and describe their thoughts during class.

Data Analysis for Students

The audiotapes of the cognitive processes were transcribed by a staff assistant. Thoughts of students were sorted into six research-generated categories and then classified into Bloom's cognitive levels. The researchers categorized the thoughts as:

- Thoughts or observations about the professor
- Nonsense or unrelated thoughts
- Thoughts connected to previous learning
- Thoughts about past experiences prompted by class subject matter
- Deeper learning/questioning thoughts
- Thoughts about behavior that got/maintained attention

Findings and Results

Assessment of Cognitive Levels Reached by Professors

Professors in this study taught 43% (see Table 2) of the time at the knowledge (compilation of first three categories) level of cognition (range = 8-18%), 30% at the comprehension (translation and interpretation) level, (range = 10-20%), 7% at the application level, (range = 4-9%), 7% at the analysis level, (range = 6-8%), 7% at the synthesis level, (range = 4-10%), and 6% at the evaluation level, (range = 2-12%). The most frequently utilized classroom discourse was at the "knowledge of specifics" level. The least frequently utilized classroom discourse was at the "application, analysis, synthesis, and evaluation" levels.

Table 2
Assessed Level of Cognitive Instruction

Level of cognition	Range (%)	Total (%)	Range (f)
1.0 Knowledge of specifics	8 - 18	17	45 - 81
1.2 Knowledge of ways and means of dealing with specifics	5 - 12	11	27 - 63
1.3 Knowledge of universals and abstracts	4 - 18	15	29 - 84
2.0 Translation	10 - 18	14	43 - 63
3.0 Interpretation	11 - 20	16	48 - 70
4.0 Application	4 - 9	7	11 - 38
5.0 Analysis	6 - 8	7	18 - 36
6.0 Synthesis (Creativity)	4 - 10	7	16 - 42
7.0 Evaluation	2 - 12	6	7 - 63

Note. 1.0+1.2+1.3 = Bloom's "knowledge" level; 2.0+3.0 = Bloom's "comprehension" level.

The most common type of thought expressed by students (68%, see Table 3) was "random or nonsense thoughts" (metacognitive processes unrelated to class subject-matter). An example was, "It makes me mad when I can't find a parking place." The second most common category of thought (12%) was "thoughts about past experiences prompted by class subject-matter." An example was processed while the professor was discussing the way pork is currently being bred for leanness. The student thought, "It doesn't matter how lean they make pork, I still won't like it." The least used category of thought was "deeper learning/questioning thoughts" (3%). An example was, "If they can put windows into cows' stomachs to measure nutrient absorption, what can we learn to help people"?

Table 3
Students' Categories of Thoughts

Categories of thoughts	Range (%)	Total (%)
Thoughts or observations about the professors	1 - 5	3
Nonsense or unrelated thoughts	37 - 86	68
Thoughts connected to previous learning	6 - 20	10
Thoughts about past experiences prompted by class subject matter	2 - 25	12
Deeper learning/questioning thoughts	2 - 7	3
Thoughts about behavior that got/maintained attention	0 - 6	4

Students' Cognitive Level of Thoughts

The most common cognitive level of students' thoughts in class was "knowledge level" (12.7%, see Table 4). Knowledge was considered in two different forms: a) searching for, and b) expressing the recognition of basic knowledge. For instance, when the professor was showing students the uterus of a pig, one student thought, “Which way do they come out [when they are born]”? This example is a search for knowledge. When a professor was discussing the domestication of different plant crops, and the student thought, “When I saw that blueberries were domesticated in North America, I remembered other fruits that were domesticated in the U. S,” the student was demonstrating an expression of basic knowledge.

Table 4
Comparison of Professors’ and Students’ Cognitive Level Reached During Class

Cognitive level	Professors (%)	Students (%)
Knowledge	43	12.7
Comprehension	30	11.8
Application	7	2.0
Analysis	7	4.5
Synthesis	7	<1
Evaluation	6	1
Other	0	68
Total	100	100

The next most used level of cognition was comprehension (11.8%). Comprehension involves two forms: a) to understand information, and b) to question the information given. For instance, with regard to understanding information, a professor was describing the antibodies in a human mother's milk, and the student thought, "If the mother is malnourished, the children will be [malnourished] as well because there won't be enough nutrients in the milk." The questioning form of comprehension is shown in the following situation: A professor was examining the uterus of a pregnant cow, and there were no ovaries attached to the uterus. The student thought, “Why are the ovaries missing”?

The application level of thought involved an average of 2% of the students’ thoughts in class. For example, while the professor was discussing the effects of obesity on cancer rates, a subject thought, “My mom is a health nut, so she’ll have a better chance of not getting [cancer].”

The analysis level of cognition consumed an average of 4.5% of the thoughts in class. For example, when discussing evolution in class, a student was reminded of learning about evolution and creation, and wondered, “What are the components of evolution and creation that can be combined”?

Less than 1% of students’ thoughts could be classified at the synthesis level. An example of synthesis level thinking occurred during a class discussion on the differences between breast milk and formula. A student thought, “Why can’t we make [breast milk and formula] the same? I don’t know all the different hormones [contained] in milk. If I know the natural ingredients how could I combine them to make perfect synthetic breast milk”?

In this study an average of 1% of students’ thoughts in class were devoted to the evaluation level. Over two-thirds (68%) of thoughts generated by students during class were “random nonsense thoughts”; these were not classified as part of the cognitive assessment.

Conclusions

Professors in this study were generally teaching at lower cognitive levels. For example, the most common teaching behaviors recorded among professors in this study were: basic elicitation of facts, verbalizing from and/or creating graphic representations, making generalizations about concepts or ideas, summarizing and concluding from what had been said, and giving reasons for facts. When professors did teach at higher cognitive levels, the most common behaviors were: producing unique communication and/or divergent ideas, showing the interaction and relationship among elements, and applying abstract knowledge in a practical situation.

Students in this study thought primarily "random nonsense thoughts" during lectures. They rarely thought at the higher cognitive levels no matter the cognitive level at which the professor taught.

By using think-aloud protocols, comparisons could be made between the higher level cognitive opportunities given by professors during lectures, and higher level cognitive opportunities embraced by students. The data reflect that much work needs to be done to increase the frequency of opportunities offered by professors to students to reach higher cognitive levels during class. Then more work must be done to get students' thinking more closely aligned to the professors' opportunities.

In many instances this alignment can be achieved by making professors aware of techniques that can be used to reach higher cognitive levels, and by reviewing with them some basic teaching methodologies. The goal is that by providing professors with techniques and methodologies designed to increase the level of cognitive processes, a higher quality of learning will be achieved in college classrooms.

Recommendations

Based on the conclusions of this study, the researchers recommend that **professors**:

- be made aware of cognitive levels of teaching by participating in faculty seminars and workshops, or by reading literature related to teaching at higher cognitive levels.
- make students aware of the objectives of the lesson prior to the start of the lesson (Perrone, 1994), so students can focus on the specific's of the content.
- teach subject matter by linking knowledge with real-life situations and issues (Perrone, 1994). By making content relevant, students will more quickly make applications in their minds during lecture.
- assist students in the formulation of new hypotheses related to the content of the lecturer (Bloom et al., 1956).
- use more visual aids along with "user-friendly" terminology wherever possible to attract and maintain the attention and focus of students.

Based on the conclusions of this study the researchers recommend that **students**:

- discipline themselves to pay attention and focus on the materials presented.
- challenge themselves to think in-class about applications of classroom material to their everyday lives.
- analyze information as it relates to previous and future life situations.
- synthesize content to follow-through a problem and formulate new hypotheses.

- evaluate the subject-matter to determine its effectiveness in solving problems and making decisions.

Implications and Discussion

Professors

Students should receive feedback from professors throughout the duration of the class, so that students may then use the feedback to assess themselves (Terenzini et al., 1995). Self-assessment breeds a higher level of understanding of the material taught and of one's own cognitive processes, which theoretically leads students to perform at higher levels of cognition including analysis, synthesis, and evaluation.

Most importantly, however, is the clear need for professors to become aware of cognitive levels of teaching (Whittington, 1995). When professors are aware of cognitive levels of teaching, they will become aware of those classroom behaviors and teaching techniques that help students think at higher cognitive levels. They will, therefore, be able to assess their teaching, plan new lessons, and adjust their classroom behaviors to teach at higher cognitive levels.

Students

An interest in the subject material of the class played a large role in whether or not the student maintained attention (Ericksen, 1984). Although a plethora of thoughts were present during class, few were related to the material being presented. Classroom material that students could easily apply to life or associate with recent circumstances, and was most readily understood, was most easily absorbed by students.

Certain teacher behaviors stimulate students' thought processes. When professors asked for input and ideas during class, students reported being more actively engaged in the learning process; when there was interaction with the professor, there was more motivation to pay attention and participate. Students were also motivated by visual stimulation. For example, when researchers asked students what they were thinking during a given point in class, they may not recall it until a visual aid from class was placed in front of them; at that moment students could recall what the professor was discussing and what they were thinking. Students were able to describe various gestures professors had used in reference to the subject matter. They stated that when the professor asked the class to figure out problems for themselves, more thought processes were engaged.

Summary

The combination of think-aloud protocols and classroom observations allowed researchers to more deeply probe the potential gap between that which professors are saying during lectures and that which students were mentally processing. It is now important to replicate the study using broader samples of professors and students so that a knowledge base can be built. Once this cognitive relationship between professors and students is concretely established, educators can effectively assist faculty and students in enriching the teaching-learning process in college classrooms.

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A Critique

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Contribution and Significance of Research

The support from the review of literature for the theoretical base that undergirds the study contributes greatly to the significance of the research. The findings, implications, and recommendations arising from the research should be required reading for college professors taking part in faculty orientation or improvement of teaching seminars. The most important implication arising from this study is that if college professors understand better the relationship in cognitive levels of learning that exist between them and their students, then they can influence more effectively the levels of learning engaged in and used by those students. Another implication exists that teacher educators can use the findings of this study as ammunition in preparing teachers to be more effective whether in a classroom or in a field setting. While the study was conducted in the setting of college classrooms, implications exist that extension personnel or other adult educators engaged in helping people learn to reason and to make decisions could learn from this research. Then too, the implications drawn by the authors and the recommendations made for both professors and students are tied well with the findings of the research reported and with previous research. Consequently, this research makes a truly significant contribution to understanding better ways of creating an effective teaching-learning process.

Procedural Considerations

The study was very well designed, tightly controlled, and well conducted, even though much subjective interpretation of actions and thoughts of both the professors and the students taking part in the study took place. The variety in the courses in agriculture that provided the setting in which professors and students were studied contributed to the elimination of subject-matter bias being a contaminating factor that affected results.

Questions for Consideration

Would a logical follow up to this study be the development of teaching guides from many different fields with examples of students' thoughts from each of the students' categories of thoughts as used in this research to give teachers, prospective teachers, and college faculty in agriculture additional insights into what may be passing through the minds of students when in the teaching-learning setting? In addition to building the study around Bloom's six-step hierarchical system of thinking in the cognitive domain, would it be worthwhile for future researchers to use think-aloud protocols to compare the cognitive levels when professors attempt to develop the seven apperceptive levels of learning, namely, knowledge, skills, interests, understandings, appreciations, values, and ideals?