The Relationship Between the Cognitive Level of Lab Questions and the Number of Requests for Individual Help

Christopher Coulston, Hisham Sager, Thomas Reagan, Thomas Reagan and John Wiens
Department of Electrical Engineering
Colorado School of Mines

Abstract: Each week, students in our Embedded Systems class work through a set of laboratory questions. The goal of these questions is to prepare the students to complete their weekly programming assignment. As students work through these problems, they may solicit help to clarify a question. It makes sense to write instructions which are as clear as possible in order to allow students to make progress at their own rate as well as ease the burden on the lab instructor. Anecdotally it appears that questions at a higher cognitive level elicit more queries from students for clarification. This paper undertakes a quantified analysis of this observation by classifying questions according to Bloom's cognitive levels and recording the number of queries from students. Data gathered through one semester of an Embedded Systems lab shows a direct relationship between the two. Additional insights from the data are provided.

INTRODUCTION:

In order to provide students with a positive self-paced lab experience, the authors strive to provide students with: lab instructions that are as brief as possible, lab questions which show achievement of the lab objectives, and lab questions that can be answered without further elaboration from the lab instructor. One indication that the lab is achieving this is to count the number of queries from the students during lab. We wanted to know if the cognitive level of a question was a primary predictor of the number of queries generated by students. The notion of cognitive level was established in Bloom's Taxonomy of Education Objectives [2] as a way to classify the different levels of understanding associated with a conceptual domain. These objectives can be used as the basis for building assessment instruments that check a wide range of instructional goals [1].

COURSE STRUCTURE:

ECE 383 is an embedded systems class with 48 students, delivered through a 3-credit lecture and a 1-credit lab. Each lab session emphasizes the lecture topics taught that week and is supervised by a lab instructor and an undergraduate teaching assistant (UTA). During each week's 3-hour lab sessions, students work in pairs to read the lab materials, answer between 10 – 20 questions, and submit their solutions to these questions. The labs require students to: download C code to their development board, use a terminal application to interact with this program, and use an oscilloscope to measure signals on the development board (see Figure 1).

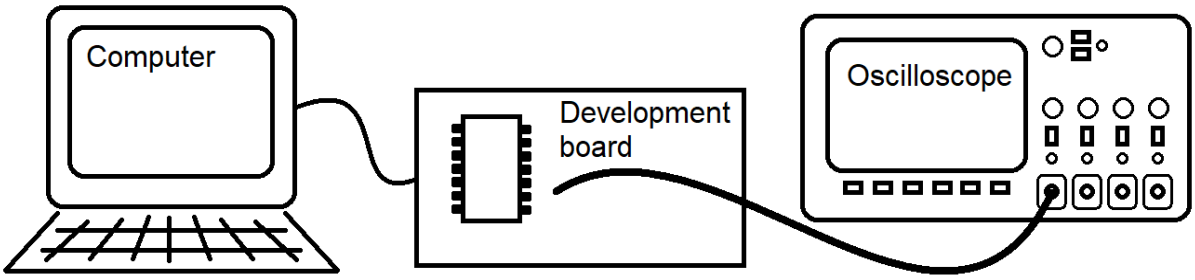

Figure 1: A typical lab setup includes a PC running the compiler and terminal application, a development board with microcontroller and peripherals, and an oscilloscope.

The questions asked during a lab session focus on: the compiler, the C-code, the microcontroller, the peripheral device on the development board, the C-code behavior observed with a terminal application, and the C-code behavior observed with an oscilloscope.

TERMINOLOGY:

For the purposes of this paper, the relevant terminology arises from cognitive level and student queries during the lab session. The cognitive level of a question is based on corresponding cognitive domain from Bloom's Taxonomy [2]. From lowest cognitive level to highest, these six

levels are knowledge, comprehension, application, analysis, synthesis, and evaluation. All the lab questions come from the first three levels.

Knowledge is recognition of facts or terms without necessarily understanding what they mean. Example questions classified at this level include:

- From the tech docs, what is the minimum period of the EEPROM serial clock?
- Capture the waveform on RC2 with the oscilloscope.

Comprehension involves translating or interpreting facts. Example questions classified at this level include:

- What is the fastest rate data can be written to the EEPROM?
- Measure the duty cycle of the waveform on RC2 using the oscilloscope time division information.

Application requires using acquired knowledge to solve problems in new situations. Example questions classified at this level include:

- Can we write a 64-byte buffer to the EEPROM before a new buffer is filled?
- Based on the oscilloscope FFT of the waveform on RC2, devise an argument about the shape of the time-domain waveform.

The second aspect of terminology is that of a query. A query is defined as a student team requesting help with a question. A query counts once even if the student team request additional help with the same question.

EXPERIMENTAL METHOD:

Before each lab, the instructor creates a diagnostic sheet for the UTAs. The diagnostic sheet contains a table with one row for each question and four columns. The columns record (1) the question number, (2) the cognitive level of the question, (3) the number of queries asked for the question, and (4) notes. During lab, the UTA records a tally mark for each query and, optionally, may record the nature of the question posed by the student. The tally marks are aggregated over all the lab sections held that week. In the next section we correlate the number of queries against the cognitive level in order to answer the experimental question.

EXPERIMENTAL RESULTS:

A total of 202 different questions have been asked over 13 lab sessions during the semester. Table 1 shows the breakdown, by cognitive level, of the number of questions asked over all the labs, the number of queries, and the ratio of the number of queries per question.

Table 1: For questions of a given cognitive level, their total count (over all the labs), number of queries and the ratio of the two.

Cognitive Level	# Questions	# Queries	#Queries/#Questions
1	97	168	1.7
2	82	169	2.1
3	23	63	2.7

The ratio of queries to questions in Table 1 normalizes the number of queries showing that as the cognitive level increases so does the number of queries. Figure 2 explores the relationship between the queries and questions by examining the distribution of the number of queries asked per question.

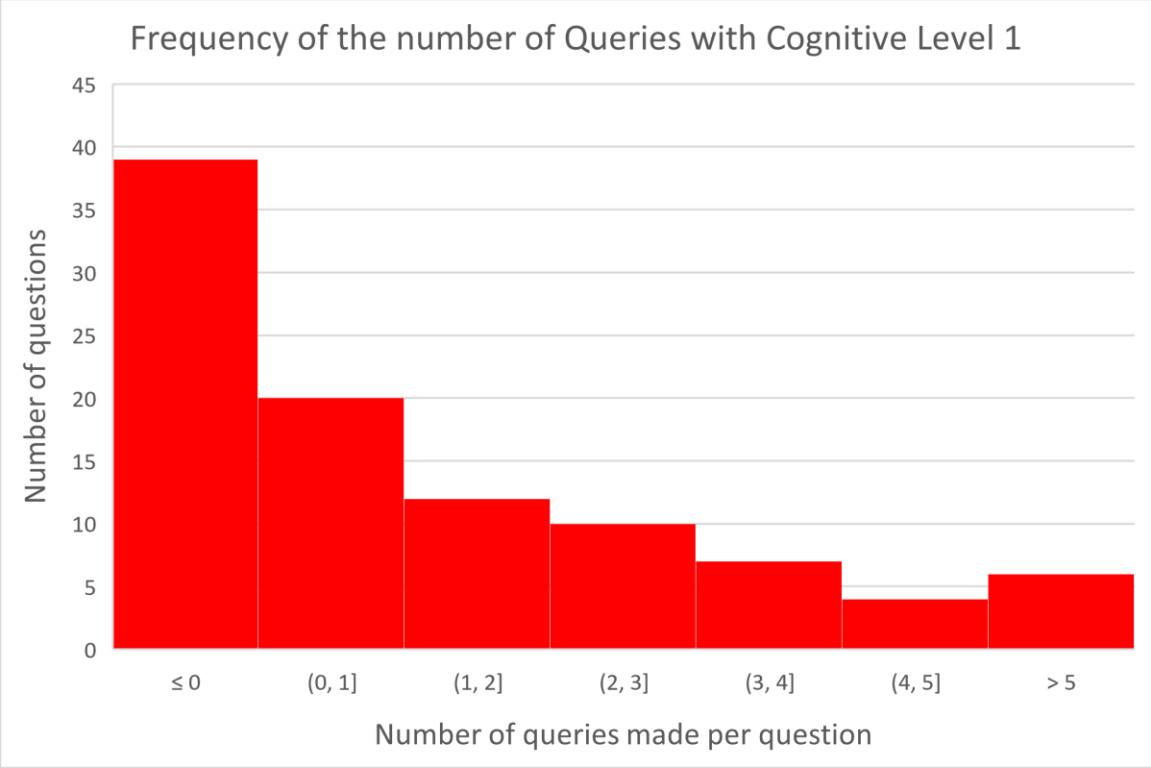

Figure 2: A histogram of the 97 questions at Cognitive Level 1, showing the number of queries asked for each question.

In Figure 2, 39 of the 97 questions or 40% of the questions with Cognitive Level 1 had no queries across all the lab sections. Seventy three percent of the questions had two or fewer questions. A small percentage, 6% of the lab questions, had six or more queries.

Question with a high number of queries would seem good candidates for re-writing and in some cases, this is warranted. However, in other cases, these highly queried questions arose from unfamiliarity with the equipment. The two most queries questions came from early labs that

required setting up an oscilloscope. To explore this, Figure 3 shows a plot of the number of questions and queries related to oscilloscope.

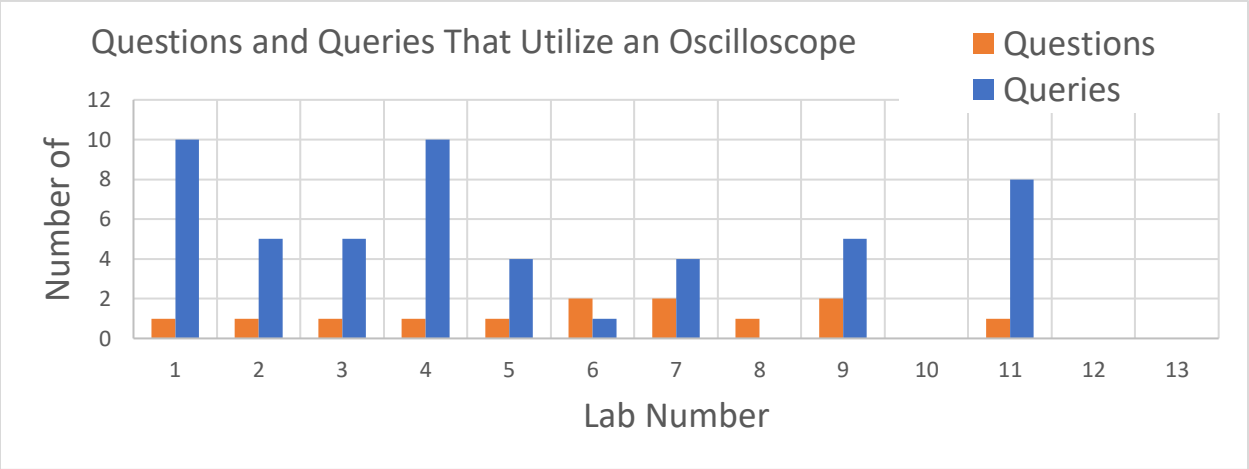

Figure 3: The number of questions and queries for Cognitive Level 1 questions that utilized an oscilloscope across all the labs.

Figure 3 shows that number of queries tended to decrease as the term progresses. Labs 1 through Lab 4 had four questions and 30 queries while Labs 5 through Lab 13 had eight questions and 14 queries. Overall, 24% of the questions required an oscilloscope to answer and these questions accounted for 37% of the queries. Meaning that instrumentation questions were more likely to require assistance.

CONCLUSIONS:

A certain amount of interaction between instructor and student in a lab environment should be expected and encouraged. An engaged student will often see connections to diverse concepts which may span the topics of the semester. A lab environment provides a less structured and less time-constrained environment in which these ideas can be posed and discussed with the lab instructor. However, lab instructions themselves should be understandable with minimal input from the lab instructor or assistants. This paper shows how lab questions classified according to Bloom's cognitive levels have a direct relationship to the number of queries that will be elicited. Using the insights from this paper, lab instructors should expect questions with a higher cognitive level will require more support.

REFERENCES:

[1] Clay, B. "Is This a Trick Question?" Kansas Curriculum Center, October 2001.

[2] Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H.; Krathwohl, D. R. **Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.** New York: David McKay Company, 1956.