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Instructional Note

Integrating Conceptual and Quantitative Knowledge

Matthew Metzgar
Department of Economics
Belk College of Business
University of North Carolina at Charlotte
Charlotte, USA, NC 28223

ABSTRACT

There has been an emphasis in some science courses to focus more on teaching conceptual knowledge. Though certain innovations have been successful in increasing student conceptual knowledge, performance on quantitative problem-solving tasks often remains unaffected. Research also shows that students tend to maintain conceptual and quantitative knowledge in different mental domains.

Traditional end-of-the-chapter problems typically have either a conceptual focus or a quantitative focus. This paper discusses the potential of multi-part problems that ask students the same question in both a conceptual and a quantitative way. The author highlights his recent experience using these problems in an upper-level economics course.

Keywords: Intermediate macroeconomics, teaching, conceptual knowledge, quantitative knowledge

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Introduction

In many science courses, there has been an increased focus at the university level towards conceptual knowledge (Gooding & Metz, 2011). This has led to teaching innovations such as Conceptests which are used in physics, chemistry, economics, and other subjects (Mazur 1997). While these innovations have been successful for increasing conceptual knowledge, student performance on quantitative problem-solving often remains the same (Valiotis 2008).

Exams often present multiple-choice problems that tend to have either a conceptual focus or a quantitative focus. Problems at the end of chapters in economics textbooks also tend to have either a conceptual focus or a quantitative focus. In comparison, problems faced in the real-world are often complex in nature. These context-rich or "whole" problems often require a combination of conceptual and quantitative analysis to produce an answer.

Previous research has shown that students often separate conceptual and quantitative knowledge rather than integrating it (Hammer 1989). Without an integrated framework of knowledge, students may not be fully successful when trying to solve complex real-world problems.

This paper discusses findings from a large Intermediate Macroeconomics class at a large Southern public university. Unique multi-part questions were created to test for student coherence in knowledge across conceptual and quantitative domains. Student answers from sample questions are analyzed for knowledge coherence across these domains.

Background

A casual review of Intermediate Macroeconomics textbooks shows that many of the end of the chapter problems tend to have either a conceptual or quantitative focus. For example, one popular Intermediate Macroeconomics textbook (Dornbusch et al, 2011) specifically puts its end of the chapter problems into three labeled categories: conceptual, technical, and empirical.

For another example, here are a few typical end-of-chapter problems from a popular intermediate Macroeconomics textbook (Mankiw 2012):

"In the country of Wiknam, the velocity of money is constant. Real GDP grows by 5 percent per year, the money stock grows by 14 percent per year, and the nominal interest rate is 11 percent. What is the real interest rate?" (Quantitative focus)

"Some economists believe that taxes have an important effect on the labor supply. They argue that higher taxes cause people to want to work less and that lower taxes cause them to want to work more. If this view is correct, how does a tax cut affect the natural level of output?" (Conceptual focus)

"Consider an economy described by the production function: Y = F(K, L) = K0.3L0.7. Assuming no population growth or technological progress, find the steady- state capital stock per worker, output per worker, and consumption per worker as a function of the saving rate and the depreciation rate." (Quantitative focus)

In addition, some end of the chapter questions may have multiple parts, where one part may be a conceptual question, while another part may be a separate quantitative question.

A potential problem with such an approach is that students may not fully integrate conceptual and quantitative knowledge. Expert thinking is characterized by a high degree of coherence between conceptual and quantitative thought (Reif and Heller, 1982). Students may retain their novice-like separation of the two domains if they are only confronted with these one-domain problems.

A way to test for coherence is to simply ask students the same question in two different ways: conceptual and quantitative. This is precisely what was done by Sabella (1999). This research did not find a high correlation between scores on conceptual questions versus quantitative questions that asked virtually the same thing. Additional research by Chandralekha (2008) showed that students tended to answer conceptual and quantitative questions with different mental processes.

Table 1 shows the results from an example question in that study.

Table 1:
Example question from Sabella (1999):

	Conceptual Question		
Quantitative Question ↓	Correct	Incorrect	Total
Correct	11%	34%	45%
Incorrect	6%	50%	56%
	17%	84%	100%

In this example, only 11% of students were able to successfully answer the same question in both a conceptual and quantitative format.

What is more interesting is that students would often give contradictory conceptual and quantitative answers on the same question. This suggests that students are using one mental domain to answer conceptual questions, and another domain to answer quantitative questions. The fact that some students would put down answers within a question that contradicted each other may show they are still maintaining their novice-like thinking on the subject.

Case Objective

Given the results of Sabella (1999) and other research showing a disconnect between student conceptual and quantitative knowledge in physics and other subjects, it is of interest to see if the same holds true for students in economics classes. It was hypothesized that students in a given Intermediate Macroeconomics class may be also not integrating conceptual and quantitative knowledge. To test this hypothesis, unique sequenced problems were constructed for exams. The first problem asks the question in a conceptual manner while the next problem asks the same question in a quantitative manner.

Assessment Method

New exam questions were created by the instructor to test for student conceptual and qualitative knowledge coherence. These questions were asked sequentially with the conceptual question first and the quantitative question second. Two sample questions used in actual exams follow.

>>>>>>>>>>>>>>
Example question #1:

1. Assume Argentina has the production function:

$$Y = F(K, L) = K^{\alpha} L^{1-\alpha}$$

If Argentina increases its savings rate, is it always the case that this will lead to a higher level of consumption per worker?

A) Yes
B) No

2. Assume $\alpha = 0.5$. Assume 10% of capital depreciates each year. What is the level of consumption per worker when Argentina saves 40% of output, compared to 60% of output?

A) 1.6 & 3.4

B) 2.4 & 2.4

C) 3.4 & 6.2

D) 1.6 & 6.2

(HINT: Are your answers congruent?)
>>>>>>>>>>>>>>

Example Question #2

>>>>>>
Assume there is a supply shock, but the Fed reacts to keep inflation at the same rate as last period. Assume citizens' expected inflation equals last period's inflation, β (beta)= 0.3, and the natural rate of unemployment is 7%. Assume there is a supply shock of 0.03.

1. True or false: In this particular case, a supply shock will increase unemployment.

A) True

B) False

2. Unemployment during this supply shock will be:

    A) u = 5.2%

    B) u = 7%

    C) u = 14%

    D) u = 17%

(HINT: Are your answers congruent?)
>>>>>>>>

Note that both questions also contained a "hint", which prompted students to recognize that these are related items.

Over the course of a semester in Intermediate Macroeconomics, dozens of these questions were placed on quizzes and exams. All of these questions were in the multiple-choice format. Student responses were compiled and analyzed. While this case study was not designed for a full analysis of all results, an analysis of sample questions follows in the next section.

Results and Discussion

Student responses were analyzed on a variety of these two-part questions. Two questions (the example questions from above) were selected as representative of typical student response patterns. The student responses to these two questions are analyzed below in regards to the correlation between conceptual and quantitative knowledge.

Table 2 presents the results from the first example question.

Table 2:
Results from Example Question #1

	Conceptual Question		
Quantitative Question ↓	Correct	Incorrect	Total
Correct	44%	2%	46%
Incorrect	37%	17%	54%
	81%	19%	100%

On this question, a large majority of students correctly answered the conceptual part while less than half correctly answered the quantitative part. Of those students getting the quantitative part correct, 95% of these students also correctly answered the conceptual part of the question. This suggests a possible integration of conceptual and quantitative knowledge for this subset of students, and perhaps a greater degree of coherence than observed in physics students.

One issue with the results is that the number of response options for each part of the problem was not constant. The conceptual part had two possible answers (true/false) while the quantitative part had four possible responses. The fewer number of response options on the conceptual part may then have led to an overestimate of the number of students who actually understood the conceptual part of the question.

The student responses on these questions were further analyzed to detect any contradictions. It turned out that 14% of students selected answers within the problem that directly contradicted each other. In other words, their conceptual answers would predict changes in one direction while their quantitative answers were predicting changes in the opposite direction. These contradictions were in spite of the "hint" given that the answers should be congruent for the two parts.

One possible explanation is that some students were not confident of their knowledge for the problem and were simply guessing. Also, it is possible that students were "hedging their bets" and choosing to go different directions on each part of the question.

Class discussion with the students after the exams revealed that this generally wasn't the case. Many students were answering the conceptual question based on their intuition, and then they would separately tackle the "numbers" part of the problem.

Table 3 presents the results from the next example question.

Table 3:
Results from Example Question #2

	Conceptual Question		
Quantitative Question ↓	Correct	Incorrect	Total
Correct	62%	2%	64%
Incorrect	23%	13%	36%
	85%	15%	100%

On this question, there were again more students correctly answering the conceptual part of the question versus the quantitative part. This may again be an artifact of the fewer response options for the conceptual part. 96% of students answering the quantitative part correctly also correctly answered the conceptual portion.

This time 13% of students put answers that directly contradicted each other. These mistakes covered all the varieties of contradictory responses. For example, students predicted from the first part that unemployment would increase yet chose answers in the quantitative portion that had unemployment decreasing. Alternatively, students would predict that unemployment would decrease and yet choose the quantitative answer where unemployment remained the same.

Even after the intent of these two-part questions was discussed in class, a portion of students still would put contradictory answers on future exams. Therefore, promoting awareness of these contradictory answers did not lessen their frequency.

Overall, these results show that some students are not able to integrate conceptual and quantitative knowledge given typical multiple-choice problems. This would then suggest that either other types of problems should be used in exams, or that teaching methods should be altered to aid in knowledge integration.

CONCLUSION

The goal of this paper was to examine how students in an Intermediate Macroeconomics class integrate conceptual and quantitative knowledge for related questions. The results show that when a question is asked in both a conceptual and quantitative way, the percentage of students answering each part correctly is not consistent. This may have been biased due to the unequal number of response options per question.

This study also showed that students will indeed put contradictory conceptual and quantitative answers within a given problem. While this may be due to guessing, discussion with students suggests that many are using separate mental processes to answer the conceptual and quantitative parts of the question. Therefore, the hypothesis that students are not integrating conceptual and quantitative domains merits further study.

Given this, presenting problems at the end of a chapter into separate categories of conceptual and quantitative may not be an effective way to integrate student knowledge. When presenting problems in this manner, different teaching protocols may be needed to help students integrate knowledge. Alternatively, it may be more effective to use whole or context-rich problems at the end of a given textbook chapter as way to help students integrate conceptual and quantitative knowledge.

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