Making Connections: Using Classroom Assessment to Elicit Students' Prior Knowledge and Construction of Concepts

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Abstract

Students bring prior knowledge and experiences to the classroom. According to the constructivist learning theory, students incorporate new knowledge into their existing knowledge frameworks. We used Classroom Assessment Techniques in an information technology course to elicit the construction of knowledge process. We found that CATs and instructor feedback can help shape and reveal this construction process. Some students claimed that the CATs helped put new ideas into their own words and helped them simplify the concepts.

1 Introduction

Students do not enter a course with a blank slate; rather, they come to the classroom with many experiences and ideas [2]. The learning theory of constructivism supports the view that human learning is constructed as students build new knowledge on previous experiences and prior knowledge [8, 3, 7]. This prior knowledge influences how the learner understands new concepts. In this model, learning is an active process controlled by the learner as she incorporates new knowledge with her previously gained knowledge. It is important for instructors to elicit students' prior knowledge and monitor inconsistencies that may arise as learners try to incorporate new knowledge within their current framework of understanding. Students and instructors need learning experiences to help guide and monitor knowledge construction.

Classroom Assessment Techniques (CATs) allow instructors to assess students' understanding of concepts [1]. CATs are usually designed for two purposes: 1. to help instructors detect if students are understanding what is taught in a course, 2. to help instructors get feedback about their teaching. By using CATs frequently, instructors can monitor students' learning through active learning experiences. Example techniques include Muddiest Point, One Sentence Summary, Extended Analogy and Concept Mapping. These activities serve as formative, ungraded assessment tools, giving the instructor an indication of students' levels of understanding. CATs are distinguished from short quizzes since students usually complete the activities anonymously, encouraging students to be honest about their understanding of the material. In our work, we not only used CATs to detect students' misunderstandings, but also to elicit how the construction of knowledge process occurs.

When using assessment techniques, it is crucial for the instructor to give feedback to the students [2]. Learners build theories based on evidence. Sometimes this evidence is incomplete or biased, but learners will go to great lengths to build frameworks to support theories [5]. If students are building incorrect theories, it is important to modify students' ideas as early as possible. The feedback and the activities themselves can create experiences for students to correctly connect new knowledge to their prior knowledge.

We used Classroom Assessment Techniques in a fluency in information technology course to provide a mechanism for the instructor to monitor the learning process. Students bring prior knowledge and experiences with HTML, computers, computing, databases, and the Internet to the classroom. Our research investigated how Classroom Assessment Techniques can be used to elicit the construction of knowledge process, how instructors respond to shape the construction, and how students perceive CATs as helping this process. We show that CATs can be designed to shape the knowledge construction process in addition to assessing students' understanding. We outline the methods used in a two-term study, report the results of the CATs used to elicit the construction process, and give implications for teaching and research.

2 Methods

Our work centered on one main research question: How can classroom assessment techniques elicit students' construction of knowledge? We were interested in using techniques to help mold this construction process. Also, how can feedback provided in response to the assessment techniques help shape the construction process?

2.1 The Classroom

We conducted studies in two academic quarters in an information technology fluency course at a large university. Students attended three 50-minute lectures and a two-hour laboratory each week. We conducted our study of classroom assessment in the lecture portion of the course. Total enrollment in each course started at 150 students, but dropped to approximately 120 students by the end of each quarter.

The course included an introduction to computer basics, information storage, HTML and web design, basic networking, programming in Visual Basic and database applications. The course is intended to expose students to several computing topics in order for them to become fluent in information technology. The course is not a requirement in the Computer Science or Computer Engineering majors at this university. Thus, students from many academic disciplines were enrolled in the course. The instructor for the first quarter of the study was a lecturer from the Computer Science and Engineering Department while the lecturer for the second quarter was from the Information School.

2.2 Materials

We developed CATs specifically addressing content covered in the course, designed to help mold the construction of knowledge and elicit students' prior knowledge of the concepts listed in Table 1.

2.3 Procedures

We met with the instructors to provide background information about the purpose of Classroom Assessment Techniques. During the first quarter of the study, we created the CATs with the instructor's input and approval. Since answers were anonymous, students in attendance could make a choice about turning in their responses. After students completed the activity (usually taking 5 - 10 minutes during lecture time), we categorized the answers for the instructor. The instructor could then use the results to provide feedback to the students. During the second quarter of the study, we developed the CATs with the instructor's input and approval, but let her categorize the responses herself. We changed our protocol since this approach is sustainable in the long term, without our intervention during the feedback loop.

In addition to the CAT responses, we collected qualitative data from the instructors and students and analyzed the data according to our research questions [4]. We interviewed (60 - 90 minutes) the instructors to get their perspective on using the CATs and surveyed the students with the following open-ended questions: 1. Which of these activities were most helpful to your learning, and how?, 2. Do you think your responses to these assignments have affected the instructor's teaching?, and 3. Do you have any other comments about these activities?

3 Results

In order to find out how the CATs can help elicit the construction of knowledge process, we look at the responses submitted anonymously by the students. We also describe how the instructors responded and how they felt they responded as supported by observation notes and interview notes. We use the student survey responses to glean themes about how CATs helped students in constructing knowledge. We performed detailed analysis for this study; this process is not necessary for instructors when looking through the responses. The instructor during the second study spent about 15 minutes looking through the responses for each CAT.

3.1 Construction of Knowledge Through CATs

Digital Representation We performed content analysis on the Digital Representation CAT with a single idea as the unit of analysis [9]. Since the unit of analysis was a single idea, one student could have many ideas about digital representation. The categories and number of students with responses fitting the categories are listed in Table 2.

Many students had correct interpretations of digital representation as seen in Table 2. It is interesting that many students constructed new knowledge of digital representation based on their prior knowledge of language and communication. Several students described digital representation as the language a computer understands or the way the computer communicates. This idea about communication was not discussed during the lecture. One assertion is that students bring prior knowledge about how the computer exhibits human-like characteristics in understanding languages. One student wrote about digital representation: "It's the way we as people talk to computers." Another student wrote: "computers don't understand English, but they do understand numbers."

We can also get a glimpse of how students construct knowledge, by tying new knowledge to several different ideas. Several responses spanned more than one category, showing that the students have a more broad understanding of the concept. In the two studies, 13 and 46 students respectively gave responses spanning three or more categories.

Variables We used two different CATs to elicit the construction of knowledge process about variables. In the first study, students wrote one to two sentences to describe a variable in computer programming. We performed content analysis on the responses to the CAT in a similar manner as for the Digital Representation CAT. In the second study, students wrote down all the words and phrases they associated with variables in computer programming. We coded the

Table 1: **This table lists the content, type and activity for the CATs used in the study. The Question/Activity lists what was presented to the students (either orally or in written form) and the Study Quarter lists the quarter in which the assessment technique was used.**

Content (CAT Type)	**Question/Activity**	**Study Quarter**
Digital Representation (Directed Paraphrase)	Pretend you have a 10-year-old sister. She asks you what you learned in school today. Explain to her the concept of digital representation.	1 and 2
Variables (One Sentence Summary)	Describe a variable in computer programming in a sentence or two.	1
Variables (Focused Listing)	List all words and phrases that you associate with a variable in computer programming.	2
Iteration (Application Card)	Think about where you see iteration in the world, in a gadget, or in a software product. Choose one scenario where you see iteration happening. Describe the scenario and describe the event(s) that repeats. Suppose you are writing code in VB for this scenario. Would you use a For-Next loop or a Do-While loop for your scenario? Why?	2
Database Schemas (Extended Analogy)	You just learned about schemas and databases. Try to come up with a new analogy that fits the following sentence: A schema is to a database as a _ is to _. Explain why your relationship holds.	2

Table 2: **Content Analysis for the Directed Paraphrase CAT on the topic of "digital representation". The first study (1) had 94 student responses and the second study (2) had 103 responses. The number reflects the percentage of students with responses in the category. Some responses spanned more than one category.**

Category Description	**Percent**	
	1	**2**
Symbols, encoding, representation	52.1	62.1
Numeric representation	41.5	66.0
Presence & absence, on/off pattern, binary	45.7	38.8
Language, communication	29.8	34.0
Bits and bytes	8.5	6.8
Invented analogy/example	6.4	10.7
Analogy/example from lecture	0.0	11.7
Other, off topic, incorrect examples	8.5	5.8

responses to the second study's CAT according to the categories that emerged during the analysis of the Variable CAT from the first study. Students completed the CAT at the end of one lecture about variables. Table 3 shows the categories and number of responses for each category.

We can see themes of how students construct the knowledge of variable in computer programming based on the word "variable" in English and variables they have seen in mathematics. Twenty-four students in the first study and 10 students in the second study had indications that a variable can hold many values simultaneously or that the value varies. It appears that some students are trying to create a model of a variable in computer programming based on their existing models of variables in other domains. The number of "Other" category responses for the CAT in the second study results from the fact that students listed many ideas associated with variables: conditionals, code, case sensitive, objects, properties, assignment, application, simplify, function, event, expression, text box, commands, syntax, input/output, program. It is important for computer science instructors to create correct models of new concepts for their students. The responses to the Variable CAT show that some students are creating incorrect models of variables in computer science.

Table 3: **Content Analysis for the CATs on the topic of "variable". 104 responses were submitted in the first study (1) and 88 were submitted in the second (2). Some responses spanned more than one category.**

Category Description	**Percent**	
	1	**2**
Type, name, value, placeholder for a value	40.4	40.9
Correct response about updating or changing values	25.0	27.2
Memory, storing a value	34.6	9.1
Incorrect response about varying or containing many values simultaneously	23.1	11.4
Symbol, representation of another thing	14.4	12.5
Mathematical concept	4.8	4.5
Other, off topic	19.2	48.9
No response	1.9	9.1

Iteration We designed a CAT about iteration to help mold students' models of iteration by connecting iteration to their daily lives. Because the answers varied widely, we do not list all the categories of responses here. We did categorize the responses into correct, partially correct (type of loop chosen was inconsistent with scenario provided), and incorrect. Out of 55 submitted responses, 32 students had correct answers, 13 students had partially correct answers, and 10 students had incorrect answers. At least half the students created a correct connection between the abstract concept of iteration and a concrete scenario in the world. It is interesting to report the different domains students used for this activity. Over 35 different domains were used and some are listed below:

–*Technology* (televisions, clocks, stop lights, video games, spell checking on a computer, cell phones, cameras, graphing calculators, elevator, escalator, CD players, gears in a car, assembly line)
–*Daily Life* (toys, pet feeding schedule, daily schedule, kitchen timer, hammering a nail, bus routes, roll call, preheating oven, human dishwasher, reading email)
–*Science* (polymerase chain reaction, pistons in an engine)

Some responses were incorrect, confusing the word "while" in English with "do-while" semantics in Visual Basic. The student states that walking to class is a form of iteration – right foot, left foot, right foot, etc. The loop chosen is a do-while, but the explanation is "you are certainly doing something else while walking". The student is referring to actions that are happening simultaneously, not the fact that the actions happen until a certain condition is met.

Schemas and Databases We designed a CAT to help mold the construction of knowledge through analogy. Out of 49 submitted responses, 33 students had correct analogies, 7 had partially correct analogies, 6 had incorrect analogies and 3 did not respond. Class attendance was about 75 students this day, contributing to the lower number of submitted responses. Since the responses were anonymous, some students chose not to submit their answers. Again, like we saw in the Iteration CAT, students used many domains for their analogies. Here are the most popular analogies created for "A schema is to a database as a _ is to _."

–DNA is to humans
–A recipe is to a cake/cookie/meal
–An outline is to an essay
–A map is to a journey

Here is an example explanation by one student for the map and journey analogy: "A schema is the design or map to the database. A map is the design of a road trip; therefore, a map to a road trip is an analogous relationship to a schema and a database." This CAT helped form connections for students about databases and schemas.

3.2 Feedback to Help Mold Construction of Knowledge

When using Classroom Assessment Techniques, it is important to provide feedback to help students assess their current level of understanding. This feedback can also help shape or re-shape the structure of knowledge. For one professor, he commented that the CATs helped him understand students' motivation: "They're taking their role as a student seriously. They are trying to do something, even though it may not be working for them. It's not that they're simply trying to get through the class with the least effort." For this instructor, knowing that the students were really trying encouraged him to respond to the CATs by re-explaining concepts. After the Variable CAT, he slowed the lecture pace and took more time to explain the basics of programming by showing more examples with Visual Basic. Some students noticed this feedback from the instructor. One student commented on the survey that the professor "changed the teaching because in the next class he went back to variables and explained it again."

The other instructor found an opportunity to give feedback about the Digital Representation CAT. She states about using CATs: "I sort of get confirmation. As to finding out how they're misinterpreting it. Usually the next class, I try to make it clear again. Like with the digital rep, the next day or the next class I really had to emphasize that it's not just using numbers." She took the opportunity to help re-shape students' understanding of digital representation. After each CAT was used in the course, she would spend a few minutes the next class period talking about the responses. She helped craft the construction of knowledge by sharing the really good responses, to give examples for students who still had confusion about the topic.

Some of the students also felt that the CATs helped the instructor see how information was being molded by the students. One student stated, "He is allowed to see how well the students understand what is going on and if they are confused he can take a step back and work on the subject more." Another states, "[They] help the professor know the level that we're at (how well we observe the information given)."

3.3 Students' Perceptions of Molding Knowledge

Students' perceptions of how the activities help them understand the material support the idea that CATs can help elicit the process of knowledge construction. Some students felt frustrated with the activities, giving comments such as "If you're already lost, they don't help", but most students saw at least one CAT used in the course as beneficial to their learning as shown in Table 4. The CATs helped students by promoting metacognitive thinking, encouraging them think about what they do and do not know and helping them clarify concepts in their minds [6]. In total, 48.2% of students in the first study thought CATs were helpful in promoting metacognitive thinking. Here we focus on students' responses from the second study that involve the construction of knowledge.

Two themes emerged from our analysis of the student survey responses supporting the claim that CATs help students construct knowledge. The first theme is that students perceive a benefit in applying concepts to real life. This makes

Table 4: **Percentage of students (First Study, N=83; Second Study, N=76) who thought a CAT was helpful to their learning. Students who said other CATs (not detailed in this paper) were helpful to their learning are not included in this table and account for the incomplete total.**

CAT Content	Percent of Responses	
	First Study	Second Study
Digital Representation	39.7	25.0
Variable	18.1	3.9
Iteration	—-	31.6
Database Schema	—-	9.2
All CAT Activities	2.4	7.9
None	15.7	11.8

the concept more understandable. The CATs used in the first study did not have students apply concepts to real life, so we did not have any responses to support this theme in the first study. However, in the second study 11 students out of 76 who submitted responses felt that it was beneficial to apply concepts to everyday things, with comments such as "The iteration in daily life and the analogy for the relationship between a schema and a database were helpful because they could be 'related' to something we do or see everyday." This gives some evidence that students do build knowledge on top of what they already know by relating new knowledge with prior experiences.

The second theme that emerged is that students felt like the CATs helped them break concepts into simpler pieces, helping them sort out the concepts in their own minds. Fifteen of 83 students in the first study and 12 of 76 students in the second study wrote responses related to this theme. This gives some evidence that students build knowledge by sometimes breaking new knowledge into simpler pieces before building theories. One response supporting this theme is "I had to break down a complicated subject into concepts that anyone could understand, I benefited from this." In total, 24 percent of the students surveyed (38 of 159) thought that the CATs were helpful in constructing knowledge, either by applying concepts to daily life or by simplifying ideas.

4 Discussion and Implications

Classroom Assessment Techniques can be designed to help the instructor elicit students' understanding of concepts and help shape the construction of knowledge. Since students bring prior knowledge to the classroom, it is important for educators to understand how students are making connections between new concepts and existing knowledge. This is especially crucial in the field of computer science since many students come into the classroom with computer experience. They have already started generating theories about how computers, the Internet, and databases work.

We have shown that the assessment techniques can give instructors a glimpse of how students construct knowledge. Some of the assessment techniques were also designed to help students make connections as they learned abstract concepts. Feedback is critical in order to re-shape incorrect constructions of students' knowledge. Classroom Assessment Techniques provide a channel for students and instructors to uncover how students create meaning for concepts. CATs may be a way to uncover some of the theories that students create to incorporate new knowledge with their prior experiences. Hopefully, uncovering these theories will lead to better learning.

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References

[1] Angelo, T. A., and Cross, K. P. *Classroom Assessment Techniques: A Handbook for College Teachers*. Jossey-Bass Publishers, San Francisco, 1993.

[2] Bransford, J. D., Brown, A. L., and Cocking, R. R., Eds. *How People Learn: Brain, Mind, Experience, and School*. National Academy Press, Washington, DC, 1999.

[3] Duit, R. The constructivist view: A fashionable and fruitful paradigm for science education research and practice. In *Constructivism in Education*, L. P. Steffe and J. Gale, Eds. Lawrence Erlbaum Associates, Hillsdale, NJ, 1995.

[4] Erickson, F. Qualitative methods in research on teaching. In *Handbook of Research on Teaching*. MacMillan, 1986, pp. 119–145.

[5] Norman, D. A. What goes on in the mind of the learner. *New Directions for Teaching and Learning*, 2 (1980), 37–49.

[6] Schwarm, S., and VanDeGrift, T. Using classroom assessment to detect students' misunderstanding and promote metacognitive thinking. In *Keeping Learning Complex: The Proceedings of the Fifth International Conference of the Learning Sciences (ICLS)*, P. Bell, R. Stevens, and T. Satwicz, Eds. Erlbaum, Mahway, NJ, 2002.

[7] Shepard, L. A. The role of assessment in a learning culture. *Educational Researcher 29*, 7 (October 2000), 4–14.

[8] Southwest Educational Development Laboratory. The practice implications of constructivism. SEDLetter, August 1996.

[9] Stemler, S. An overview of content analysis. *Practical Assessment, Research and Evaluation 7*, 17 (2001).