Facilitating Knowledge Construction by Learners —An Exercise in Course Design

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The *constructionist view* of learning holds that knowledge is not transferred from an instructor to a learner, but is constructed by the learner. The instructor facilitates knowledge construction by designing appropriate learning experiences. The *active learning* approach holds that learner learns best by getting involved in a learning experience. This document describes an exercise in course design to facilitate knowledge construction by learners for CS 347: Operating Systems in the January–April 2015 semester, using an innovation called *Think–Discuss–Share* (TDS) peer groups.

1 Motivation and Overview

After years of dissatisfaction with student performance—not merely poor marks, but poor quality of answers as well—and efforts to improve one's own teaching performance, the author realized that holding the view that teaching is an art failed to provide any method of tackling this issue.

Hence the author decided to look for solutions in the view that teaching is a science. It led to the primary realization that the key to dissatisfaction with student performance lay in

- failure to articulate one's expectations about the goals of a course
- failure to equip students with means of achieving the goals.

Study of literature on effective teaching and learning provided a wealth of material such as the Bloom taxonomy about domains of learning and categories of knowledge, and various learning theories and their postulates. The author decided to design a course using the following three principles that seemed common to most theories of learning:

- Relevant prior knowledge, when activated, facilitates learning
- Learners associate new knowledge with existing concepts in their mental structures
- Peer discussion helps in assimilating new knowledge and integrating it into cognitive structures.

2 Features of the course

Every course requires students to have the ability to operate at an advanced level of knowledge. However, an instructor's ability to do it through a lecture is limited because many of the insights sought to be transferred to students cannot be readily assimilated during the lecture. Home assignments permit a student to learn and master the material at her own pace. However, it is difficult or impossible to provide timely feedback on home assignments due to the large number of students. Active learning techniques provide a means of achieving it in the classroom itself, but even here it is difficult to provide feedback and guidance effectively.

These issues were tackled by planning three kinds of activities:

1. *At the start of the course:* Sensitize students about learning objectives of the course and categories of knowledge and relevant prior knowledge. This way, they would know what was expected of them.

2. *During each lecture:* List learning objectives of the lecture and the categories of knowledge at which students would be expected to operate, and have an active learning session that would provide an opportunity for discussing a focused questions in a peer group and provide TA's feedback to the peer group.

3. *Throughout the course:* Conduct quizzes and provide individual feedback, and plan assignments that would help in developing ability to structure one's knowledge.

Details of these activities are provided in the following.

(a) At the start of the course

- **Sensitizing students about learning objectives of courses:** A 30-minute introduction to the notion of learning objectives was offered in the first lecture, supplemented with a printed handout. (A copy of the handout appears as Annexure I.) It covered
  - What is learning: it enables a learner to perform specified task(s), so learning has desired outcomes
  - Categories of knowledge in Bloom taxonomy (remembering, understanding, applying, analyzing, evaluating, creating)
  - Importance of prior knowledge and need to structure one's knowledge

  - Common elements of well-known theories of learning.
- **Activating relevant prior knowledge for the course:** Each student was asked to complete a quiz/questionnaire concerning prior knowledge relevant for the course. In next class, importance of each item of desired prior knowledge was stressed and common deficiencies noticed in student responses were pointed out.

(b) In each lecture

- **Listing learning objectives:**
  - Learning objectives were listed at the start of the lecture.
  - During the lecture the objectives were related to the appropriate categories of knowledge in Bloom taxonomy.
  - Students were acquainted with specific outcomes of learning.
  - Guidance was offered on how students are expected to operate at each knowledge category. For example, how to define a concept, how to explain its operation, how and when to use or apply it, how to analyze a method, technique or system that uses the concept; how to evaluate and compare techniques or methods; how to design methods, etc.
- **Providing opportunity for peer interaction/discussion:** Each lecture had a *Think–Discuss–Share* (TDS) session of about 20+ minutes for peer interaction and discussion. (It resembles think-pair (TP) or think-pair-share (TPS) in some respects but differs in others.)
  - Students were asked to form *TDS peer groups* having 6 members (3 benches x 2). Groups were given serial numbers and retained their identities throughout the course.
  - In each TDS session, the peer groups were given a question pertaining to a higher category of knowledge, that is, either analysis, evaluation, or design. The groups were expected to have a focused discussion on the posed question and submit a written answer.
  - TAs and the instructor were available for clearing doubts and answering questions.
  - A TA gave written comments on each group's submission. The commented submission was scanned and mailed to each of the groups. This was possible because there were only abut 20 groups, though the class had 100+ students.

    - The nature of the question and the length of a TDS session provided ample opportunities for students to form and express their thoughts, validate each other's thoughts, reconcile them, and compose an answer.
    - In later part of the course, groups pleaded for more time because questions became more complex, so they were allowed to take the TDS sheets home and submit in the next class.
    - TDS submissions were *not* graded.

(c) **Throughout the course:**

  - **For developing ability to structure one's knowledge:** Students working were given two assignments on preparing of *concept maps* for a couple of sizeable topics covered in class.
    - Students worked in groups of 2.
    - A concept map was required to show all the associations the students had formed between the various concepts of that topic.
    - Students were asked to go beyond mere first level associations, and represent deeper insights they had obtained.
    - Concept maps were graded; had a total of 10% weightage in course.
  - **For assessing concept building & analysis/design ability:**
    - 5 Quizzes were conducted and graded
      - Detailed written feedback was given.
      - Conceptual clarity, self-explanatory answers, and clear expression were demanded — the motto was "*Say what you mean and mean what you say*".

3 Some observations

- All teaching was done using the blackboard (in room IC3); not a single slide was used in lectures. A standard template was used to plan each lecture, which had slots for Important concepts from previous lecture, Learning objectives, Steps in development (with optional timing), Details of TDS session, etc. (a copy is enclosed as an annexure.)

- Care was taken to ensure that all classroom matter relevant to a TDS question was on blackboard when a TDS session was conducted. It required a bit of planning but was very useful to students. It may not be easy/possible in slide-based lectures because only one slide can be displayed at a time.

- Students seemed to engage in peer discussion quite actively. Their submissions were "mostly good". They might have been better if instructor or TAs had gone around providing guidance or intermediate feedback. However, as a policy, we decided not to do that for fear that students might start depending on intermediate feedback and lose the essence of doing it all by themselves.

- The course ran in a 1.5 hour, twice a week format. Every lecture had either a quiz or a TDS session. Some lectures had both. So about 20 medium-sized meaningful questions were discussed in TDS sessions and students had an opportunity to obtain feedback, first from members of their peer group and then from the TA. In the absence of TDS peer groups and TDS sessions, few students would have tackled so many questions in a comprehensive manner.

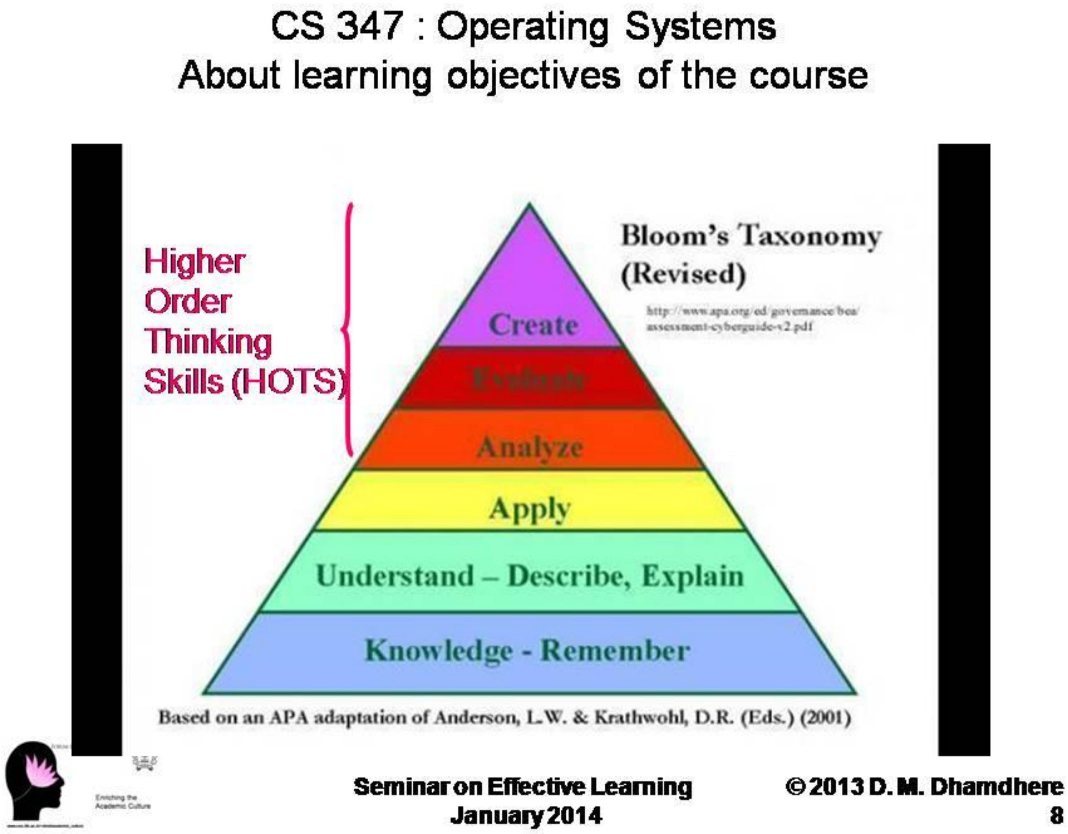
- The average mid-semester marks were 52%, which was 7% better than the previous year. The complexity of the questions was comparable; however it should be noted that no specific effort was made to make them of "equivalent" complexity. So more data is clearly needed to infer anything.

- The mid-semester answers seemed "better" than in previous years. A larger fraction of answers were at an appropriate category of knowledge, so less heart-burn for the instructor of the kind "I asked for how X is used, but the student is saying what X does", or "I asked for a comparison of A and B, but the student has simply explained what A and B do."

4 Included Documents

The following documents have been included in annexures:

Annexure I	Student handout used in first class
Annexure II	Template used to plan a lecture
Annexure III	A sample TDS session



Learning Objective	Description of objective	Action verbs for a task in objective
Creating	Build a structure, put parts together	combine, design, generate, ..
Evaluating	Make judgments about value of ideas, material	appraise, assess, justify, ..
Analyzing	Identify component parts or orgn structure	compare, contrast, separate, ..
Applying	Use a concept or abstraction	compute, construct, predict, ..
Understanding	Understanding the meaning	comprehend, explain, summarise
Remembering	Recall data or information	list, describe, identify, ..

2. How do we learn?

Bloom's taxonomy (actually designed by a committee headed by Bloom) focused on setting objectives of learning, and testing to check whether learning has occurred. That committee did not address the issue of learning.

The *constructivist view* of learning holds that knowledge is not transferred (from an instructor) to a learner, but is constructed by the learner. The instructor facilitates the construction by designing learning experiences. The *active learning* approach holds that learner learns best by getting involved in the learning experiences.

Many theories of learning have been evolved over time. We refer to the theory by Gagne, though many other theories have analogous elements.

3. Elements of Gagne's theory of learning

Gagne's theory identifies the following:

1. **Verbal information**: The kind of knowledge we can state. (Also called declarative information.)
2. **Concrete concepts:** Help to identify object properties and differentiate between objects or ideas.
3. **Defined concepts:** These are statements about attributes and relationships. Relationships help to build higher concepts.
4. **Intellectual skills:** Intellectual skills are about use of **rules**, where a rule is a statement of relationships between concepts. Application of simple rules is a basic intellectual skill. **Problem solving** is an intellectual skill that involves uses of higher-order rules in new situations.
5. **Cognitive strategies:** This is a special kind of intellectual skill that governs one's activities. It is a control process by which an individual selects and modifies her ways of attending, learning, remembering, and thinking.

4. Approach we will follow in this course

Based on the commonalities among theories of learning mentioned in the next section, we shall use the following three principles all through the course:

- Prior knowledge should be activated to facilitate learning
- Learners associate new knowledge with existing concepts in their mental structures
- Peer discussion helps in integration of new knowledge into cognitive structures.

5. Significant commonalities among theories of learning

a) Vygotsky's Zone of Proximal Development (ZPD)

- Language and social interaction are the fundamental means of education
- Learning occurs just above a learner's current level of competence
- Prior knowledge should be activated to facilitate learning.

b) Ausubel's Learning Theory

- "The most important single factor influencing learning is what the learner already knows. Ascertain it and teach accordingly."
- Learners associate new knowledge with existing concepts in their mental structures.

c) Merrill's Instructional Theory

Students learn more if

- Students are directed to recall prior knowledge
- Students are encouraged to integrate new knowledge into cognitive structure through reflection, peer discussion, debate.

Annexure II

CS 347: Operating Systems
Lecture 14 Date: 27 February 2015

Preliminaries
- Resource state models, Resource classes (SI/MI)
- Resource requests (SR/MR): >=1 unit of One/several classes
- 4 conditions for deadlock
- Deadlock prevention
- Deadlock detection

Learning objectives:
- Deadlock avoidance
- Banker's algorithm

- Static and Dynamic binding
- Memory allocation to a process
- Relocation, linking, and loading of programs
- Program forms --- relocatable, self-relocating, re-entrant programs
- Heap allocation, program fragmentation

Actual sequence:

A. Deadlock detection and resolution (10 minutes)

B. Banker's algorithm (30 mins) : upto 11.40

Consider future resource requests:
Dl can arise in future if there exists no sequence of events
by which each process can get max resources & complete
Admission criterion
Safe state, Safety of an allocation
Ex: Max (8,7,5), Alloc (3,1,3), Req (1,0,0), Tot alloc 7, Tot res 10

C. TDS (20 minutes)

- Give a scheme and ask whether it avoids deadlocks
- Dining philosophers: How to prevent deadlocks?

D. Memory allocation

Static and Dynamic binding
Memory allocation to a process: Code, static data, PCD data, stack
Compilation, Relocation-linking, and loading of programs
(compiler --> linker --> loader)
Program forms --- relocatable, self-relocating, re-entrant programs
Heap allocation---first, next, and best-fit allocation
Program fragmentation

Annexure III

CS 347: Operating Systems
Think–Discuss–Share, TDS 15: 11 March 2015

Group No ______________________

Names and Roll nos of Group Members:

______________________ ______________________

______________________ ______________________

______________________ ______________________

Q.1 The worst-fit allocator: While allocating a request for s bytes, allocate from a free area that would leave the largest area free. (*Hint:* It is the opposite of the best-fit.)

Compare the worst-fit allocator with the best-fit allocator. (Mention what criteria you are using for comparison and justify them.)

Q.2

(a) What are the situations in which the powers-of-2 allocator is a better allocator than a buddy allocator? Why? (Mention what criteria you are using for comparison and justify them.)

(b) What are the situations in which the buddy allocator is a better allocator than a powers-of-2 allocator? Why? (Mention what criteria you are using for comparison and justify them.)