Infusing Critical Thinking Skill Classification into a Software Engineering Course

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Abstract

Life long learning is important to keep oneself up-to-date in ones profession. Due to the rapid evolutionary nature of computer science, life long learning becomes even more important. Equipping the students with critical and creative thinking skills can make learning more effective. Critical and creative thinking skills can be taught either by offering explicit courses on such topics or the important skills can be infused into the contents of various courses in the computer science or computer engineering programs. Teaching critical skills along with the course contents can prove itself more appropriate than only transferring the subject knowledge (course content). Some topics may provide a very natural way to teach a critical thinking skill.

This paper describes some of our efforts in infusing the critical thinking skill of classification into a course on Principles of Software Engineering in our undergraduate computer science curriculum.

1. Introduction

Recently there has been an increasing emphasis on life long learning and one is expected to learn new things even long after finishing formal education. The mere transfer of knowledge from teacher to students is considered inadequate. To facilitate learning outside university and after formal education, many good thinking skills such as critical and creative thinking should form part of classroom teaching [2]. The best way to achieve this is to infuse these skills into regular course content [12]. This exercise also gives an opportunity to use active learning techniques in the class room. In this paper, we describe some of our efforts in infusing the critical thinking skill of classification into a course on Principles of Software Engineering.

The purpose of specifically teaching critical thinking in computer science or any other discipline is to improve the thinking skills of students and thus better prepare them to succeed in the world. But, one may ask, don't we automatically teach critical thinking when we teach our subjects, especially engineering disciplines which need rational thinking in optimizing the design while balancing many (often conflicting) requirements through judicious trade-offs? The answer to this question is often `no' for the following reasons. All education consists of transmitting to student two different things: (1) the subject matter or discipline content of the course ("what to think"), and (2) the correct way to understand and evaluate this subject matter ("how to think"). We do an

excellent job of transmitting the content of our respective academic disciplines, but we often fail to teach students how to think effectively about the subject matter, that is, how to properly understand and evaluate it. This second ability is termed critical thinking. Due to various constraints (time being the main constraint), majority of us approach content, not as a mode of thinking or as a system of thought, but rather as a sequence of stuff to be routinely covered and committed to memory. When content is approached in this lower order way, there is no basis for intellectual growth as there are no deep structures of knowledge formed and no basis for long term grasp and control. Critical thinking, in contrast, approaches all content explicitly as thinking and weaves new thinking into old. It is thinking about thinking while thinking in order to make thinking better [10].

While there is a significant amount of literature available [3, 4, 9] on infusing critical thinking skills into course content in medicine, nursing, psychology, engineering and pure sciences like physics and chemistry, very little literature is available on such efforts in computer science. It is our endeavor to bring these issues to the notice of the computer science community.

While many university administrations encourage introduction of good thinking skills and other interpersonal skills, the initial reaction of faculty is an apprehension that introduction of these (perceived to be) extra skills eat into their classroom time. On the contrary, our experience shows that explicit introduction of these important skills stimulate the students thinking and enhance their learning skills without eating much of classroom time.

Principles of software engineering course is central to most computer science programs across the world. This course is rich in content and often complemented by a project (perhaps for two semesters). The nature of its content allows for infusion of critical thinking skills in a natural fashion. In this paper, we share our experiences in infusing critical thinking skill of classification into this course content.

2. Explicit Introduction of Thinking Skills

Even though we started only recently introducing these thinking skills explicitly, we have always been using them in our teaching. Explicit introduction of thinking skills facilitates

1. students to reflect on what ways of doing specific types of thinking are good for them to practice, and what plans are the best ones for them to adopt in doing these kinds of thinking,
2. practice directed at building the habit of doing specific types of thinking, and
3. familiarity with occasions on which such thinking is appropriate or called for [12].

This helps in building a good repertoire of skills that will be useful in lifelong learning. In fact, the following principles emerged during the thinking skills movement [12] support explicit introduction of thinking skills.

- The more explicit the teaching of thinking, the greater impact it will have on students.
- The more classroom instruction incorporates an atmosphere of thoughtfulness, the more open students will be to valuing good thinking.

- The more the teaching of thinking is integrated into content instruction, the more students will think about what they are learning.

It is a well-established fact that thinking skills are most effectively taught when taught directly and deliberately [6] and there is no teaching of thinking skills in isolation from a knowledge base, nor is a knowledge base developed without a dynamic, thinking type of interaction with the content [13].

3. Classification: A Critical Thinking Skill

Classification is a critical thinking skill. It involves putting particular objects, physical or conceptual, in general categories based on the specific characteristics of the objects and defining characteristics of the categories. A systematic approach to classification can lead to better categorization of objects on one side and on the other side; it can provide a thinking map to the learners to develop better classification skills.

Two main approaches to classification are bottom-up and top-down. In bottom-up classification, we analytical study the characteristics of the object to be classified, and then keeping in mind the purpose of classification we try to map the studied characteristics of the object to be classified on to the defining characteristics of the categories. A match with maximum characteristics can be the category of the object. Top-down approach is just the reverse of the bottom-up approach. In this approach, we begin with the defining characteristics of the categories and try to find out whether the object to be classified has all or maximum of the defining characteristics of any category.

A thinking map for bottom-up classification can involve developing answers to the following questions:

1. What characteristics do the given object(s) have?
2. What categories and sub-categories do these characteristics define?
3. What purpose do we have for classifying the object(s)?
4. What way of classifying the object(s) best serves the purpose?
5. Which object(s) fall into each category?

Similarly a thinking map for top-down classification can consist of going through the following steps:

1. What are the defining characteristics of each category under which I want to classify the object(s)?
2. Determine for each object to be classified whether it has all or maximum defining characteristics of any of the category.
3. What purpose do we have for classifying the object(s)?
4. What way of classifying the object(s) best serves the purpose?
5. Which category the object(s) belongs to for the purpose?

4. Infusing Classification into a Software Engineering Course

CC2001 includes a 31 core hours on Software Engineering for a BS program in Computer Science. An instructor can find many instances of imparting knowledge where critical thinking skills can be infused into the content delivery. One such a scenario is to determine appropriate software architecture for the application to be developed. Knowing that generic architectures exist which have been in use for quite some time and it has helped the software engineers to understand the strengths and limitations of these architectures can be of great help in the development of new software systems.
With this view, the general problem can be which generic software architecture, if any, can be appropriate for the application to be developed. The problem can be better solved by using a systematic classification approach to find the best-suited architecture for the application.

5. A Model Lesson

A model lesson to infuse classification as a critical thinking skill into an undergraduate software engineering course is presented below.

A scenario
Shinning Stars is a very popular magazine. The management is interested in developing a software system that sends out reminders to the magazine subscribers at appropriate time using email that their subscriptions are due to be paid.
Knowing that four general software systems are

1. Data processing systems
2. Transaction processing systems
3. Event processing systems
4. Language processing systems

What can be appropriate category of the subscription reminder system?

Classification of Subscription Reminder System
We will use the thinking map for the top-down classification approach to determine an appropriate class for the subscription reminder system. The five steps of the thinking are:

1. **What are the defining characteristics of each category under which I want to classify the object(s)?**
   The defining characteristics of the four general classes are given in the table below:

Data processing systems	Transaction processing systems	Event processing systems	Language processing systems

Input-process-output structure	Application takes/writes data to database	Application responds to events	Application accepts a natural or artificial language as input and transforms it into another equivalent representation
High magnitudes of data	Tasks are coherent sequence of subtasks	Event timing is unpredictable	Formal description of system data is possible
Input and output are batched	Users make asynchronous requests		

2. **Determine for each object to be classified whether it has all or maximum defining characteristics of any of the category.**
   It can be restated as "what are the characteristics of the item that we want to classify?"
   Characteristics of the application under consideration, i.e., subscriber notification system are
   1. Input-process-output structure
   2. High magnitudes of data
   3. Input/output can be batched

3. **What purpose do we have for classifying the object(s)?**
   The purpose of classification is to find an appropriate architecture for the software system.

4. **What way of classifying the object(s) best serves the purpose?**
   One way to classify the application for an appropriate architecture is to map the application for maximum number of similar characteristics.

5. **Which category the object(s) belongs to for the purpose?**
   For the application under consideration, all three characteristics of the application matches with those of the data processing system. Therefore, the application can be classified as a data processing system.

6. Conclusions

In this paper, we described our experiences in infusing critical thinking skills into a computer science course proposed in CC2001 [1] as "Principles of Software Engineering". In particular, it is shown that critical thinking skills like classification can be naturally introduced in the course content. The benefits from the infusion of critical thinking skills into course content include the following:

1. Improved thinking skills in the students:
2. Lively classroom atmosphere: in view of the active learning techniques used in the course, student participation naturally improved.
3. Improved communication skills: because of the writing they have to do for critical think assignments, students communication skills improved.

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