

Infusing Parts-whole Relationship Critical Thinking Skill into Basic Computer Science Education

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Abstract

Improving the quality of student thinking should be given a high priority in any educational system as good thinking is essential in meeting the challenges of living in a rapidly changing and technologically oriented world. Research on thinking convinced that skillful thinking process can be inculcated in students if thinking skills are taught explicitly and are integrated into content instruction.

Basic critical thinking skills like determining parts-whole relationships, comparing and contrasting, classification, sequencing, finding reasons, and decision making play an important role in professional lives. These skills can be either imparted to the computer science students by offering special course(s) on critical thinking or can be infused into the course contents. Using the later approach, one model lesson on a topic from a basic computer science course proposed in CC2001 [1] as "Introduction to Computer Science" is presented in this paper. It is very natural to embed the critical thinking skills like determining parts-whole relationship into the course contents. The approach will enhance both the understanding of the computer science concepts as well as the critical thinking skills of the students.

Keywords: Critical thinking, computer science education, parts-whole relationships

1. Introduction

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. For example, while introducing students to computing systems; parts-whole analysis technique can be a very natural way to explain the topic. The approach on one hand can help the students to develop a better understanding of the topic and on the other it will make the students aware of parts-whole analysis technique explicitly.

In this paper we describe our efforts through a model lesson on a topic from an introductory course in a typical computer science undergraduate program to infuse parts-whole analysis into the course contents.

In our conventional way of teaching computer science, emphasis is on covering the contents in ways the instructors consider appropriate. Generally no or very little explicit emphasis is given to the thinking skills. Critical thinking skills place emphasis on making thinking process explicit. Combining the two approaches have the potential to enhance the learning abilities of the students. The approach can teach thinking about thinking while thinking in order to make thinking better [14].

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 [7]. It is our endeavor to bring these issues to the notice of the computer science community.

Section 2 of the paper discusses critical thinking. Explicit introduction of thinking skills is discussed in section 3. A critical thinking technique, parts-whole analysis is described in section 4, Section 5 discusses infusing parts-whole analysis into course contents by presenting a model lesson on “Introduction to Computer Systems” in which parts-whole analysis technique is infused into the teaching of the topic. Conclusions are presented in section 6.

2. Critical thinking

We begin this section with a quotation from an article by Facione [7, 8] to highlight the importance of critical thinking skills.

We understand critical thinking (CT) to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. CT is essential as a tool of inquiry. As such, CT is a liberating force in education and a powerful resource in one’s personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal.

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 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 [14]. This exercise also gives an opportunity to use active learning techniques in the classroom. In this paper, we describe some of our efforts in infusing critical thinking skills into a course on introduction to computer systems.

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 [14].

While there is a significant amount of literature available [3, 4, 11] 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 [9]. 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.

3. 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 [14].

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 [14] 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 [15].

4. Parts-whole analysis

Parts-whole analysis is one of the fundamental thinking skills that help in analyzing an object, system, process, definition or a concept to understand the matter under consideration. It involves identifying the parts that constitute the whole, the function of each individual part and its contribution to the function of the whole (how the parts work together to deliver the function of the whole). For example, an essay typically contains an introduction, a body and a conclusion. Each of them plays a specific function and they combine together to make a coherent essay. Parts-whole analysis not only helps in the analysis but can also contribute towards creativity and synthesis. Knowing the parts and their functions allows one to change the compositions and try out new sensible combinations and synthesize new working systems.

Most of us use parts-whole analysis on many occasions. But these unconscious applications of this technique are often superficial and some of the common mistakes are

- We define parts based on their appearance at first glance (hasty),
- We do not think of subdividing parts into other parts (narrow), and
- We do not connect parts together in relation to the whole (scattered thinking).

A systematic and explicit introduction of this technique helps in mastering the effective use of parts-whole analysis avoiding the above-mentioned mistakes. The following four questions capture the essence of parts-whole analysis. Answering these questions one by one facilitates skillful thinking and provides a thinking map for carrying out parts-whole analysis skillfully:

1. What smaller things make up the whole?
2. For each part, what would happen if it was missing?
3. What is the function of each part?
4. How do the parts work together to make the whole what it is?

Thinking map provides a basis for organizing contents to be delivered in a class.

5. Infusing parts-whole analysis into course contents

We choose a typical basic computer science topic “*Introduction to Computer Systems*” to demonstrate that how a lesson can be organized in order to infuse critical thinking into the course contents. Rather than defining our objective only to introduce the students to a computer system we set two objectives for the lesson:

1. Students should be able to explain what a computer systems is and how it functions
2. Students should learn how to perform parts-whole analysis skillfully

5.1 A model lesson

Model lesson consists of a brief introduction to parts-whole analysis technique and then the topic is explained as an application of the technique.

5.2 Parts-whole analysis

When we look around us, we are surrounded by objects. Chairs on which we sit, pens with which we write, books that we read, clubs or societies to which we belong, and the computers that we use are all objects. When we look closely, these objects which we talk about as one thing are actually different parts put together in a very specific manner. Each part has its function or role in the whole object. The chair has legs, seat, arms, and back. The book has cover page, table of contents, chapters, sections, paragraphs, index, and back page. The computer consists of a keyboard, a monitor, and a processing unit.

Parts-whole analysis is a thinking skill. In this lesson we will learn how to do parts-whole analysis skillfully and apply it to have a better understanding of computers in terms of their parts and functions.

Very first question one can ask is “is it important to know parts-whole relationship to understand things around us?” A closer look at any object, physical or conceptual, can reveal that a “whole” is not just an ad hoc combination of “parts” but “parts” with specific functions have been put together in a very specific way to have the “whole”. Same parts may be put together in a different manner can end up in an altogether different “whole. This simply implies that knowing the parts and their functions with little more involved thinking can lead to creating an all new whole. Understanding the functionality of parts can lead to better maintenance of the whole. In addition, understanding the functionality of individual parts can lead to better understanding of the whole.

Normally we feel that parts-whole relationship is a very intuitive phenomenon. Not really, because parts-whole analysis is not just having a superficial understanding of an object, as we normally do. Rather it is looking deeper into parts, parts of parts, and so on until further parts-whole analysis becomes unnecessary. Moreover, a little deeper thinking on our thinking about parts-whole analysis will make us realize that a “whole” is not a scattered ad hoc combination of “parts”. It is an organized composition of parts.

In case we are convinced that a skillful parts-whole analysis is necessary then the logical concern arises: How can we determine parts-whole relationships skillfully?

Determining how parts function in relation to whole is a basic analytical thinking skill. A strategy for determining parts-whole relationships can be to find answers to the following questions:

1. What smaller things make up the whole?
2. For each part what will happen if it was missing?
3. What is the function of each part?
4. How do parts work together to make the whole what it is?

Answering the above four questions in the order as given above provides a thinking map for determining parts-whole relationships. We will use these questions to understand what a computer system is.

5.3 A computer System: Parts-whole relationship view

In order to develop our understanding of a computer system, let us try to answer the four questions outlined in the previous section.

What smaller parts make up a computer system?

Mainly a computer system consists of hardware and software.

What would happen if hardware is missing?

There will be no computer.

What would happen if software is missing?

There will be computer hardware but it cannot work

What is the function of hardware?

Hardware provides the necessary circuitry to store and process the instructions

What is the function of software?

Software generates instructions that should be processed by the hardware.

How do parts work together to make the whole what it is?

Software generates instructions that are processed by the circuitry and it enables a computer system to take input and process it to produce output.

Now in order to develop a deeper understanding, we can ask the same questions about each part learned so far.

What smaller parts make up computer hardware?

Keyboard, mouse, monitor, processing unit

What is the function of keyboard?

Keyboard is an input device. It is used by the users to provide input to a computer system.

What would happen if keyboard is missing?

User has to find alternate mechanisms to provide input to a computer.

Similarly all other parts should be discussed and a concluding answer to the following question should be developed.

How do parts work together to make the whole what it is?

Repetitive use of the above questions will ultimately help to develop an understanding of a computer system with infused parts-whole analysis analytical thinking skill.

6. Conclusions

In this paper, we described our experiences in infusing critical thinking skills into a basic computer science course proposed in CC2001 [1] as "Introduction to Computer Science". In particular, it is shown that critical thinking skills like parts-whole analysis 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.

7. Acknowledgements

The authors would like to thank the Deanship of Academic Development at King Fahd University of Petroleum and Minerals Saudi Arabia for supporting this research work.

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