Expertise in Engineering Learning: Examining Engineering Students' Collaborative Inquiry of Computer Systems

Yuen-Yan Chan, The University of Hong Kong, Pokfulam Road, H.K., Hong Kong SAR, yychan8@hku.hk

Abstract: This work studies how expertlike engineering undergraduates learned about computer systems modeling and simulation through collaborative inquiry. From a close examination of the student artifacts, noticeable differences between expertlike engineering learners and their non-expertlike counterparts were found. Such differences were consistent to literature. Although inquiry-based learning and collaborative learning have long been recommended as pedagogy to enhance student learning and knowledge construction, experts and novices still demonstrate various differences in their collaboration and inquiry process.

Introduction

Engineering is one of the difficult knowledge domains. Engineers not only need to understand how computer systems work, they also need to know how to develop such systems and to optimize their performance. Traditional computer systems often involve only one client (the entity that requests) and one server (the entity that responses with requested service). However, as technologies advances, nowadays computer systems such as those for handling stock exchange and supply chain management often adopt a multi-tier architecture. A number of recent studies take in the perspective of learning sciences to look into engineering student learning (such as Chan, 2007; Chan, Hui & Dickinson *et al.*, 2009).

There are a few works that distinguish between expert and novice learners in the engineering subject domain. For example, Basili, Selby and Hutchens (1986) studied how experts and novices developed software with specific requirements, and found that experts could analyze the documents using their "own" way and work effectively, but novices needed training and required a procedural approach. Schenk, Vitalari and Davis (1998) investigated how expert and novice system analysts approached the information systems differently and accomplished the tasks differently. They identified the differences in their problem-solving approach in which experts analysis were more creative. Soloway and Ehrilich (1984) explicitly designed an experiment to study between expert and novice programs and notice that expert programmers possessed and used programming plans and rules of programming discourse when writing programs, while novice programmers did not.

Contributions of the Current Work

I am interested to find out the characteristics demonstrated by expertlike engineering learners who are engaged in a collaborative inquiry learning environment. I distinguish and illustrate the differences between expert and novice engineering learners with the subject contents of computer systems modeling and simulations. In particular, I attempt to characterize expertlike engineering students in terms of the followings:

1. How they approach to the problem? Do they approach it with a specific goal?
2. How are their problem-solving behaviors different from their peers? How they make use of given information and available resources to solve the problem?
3. How they organize and represent the subject knowledge?
4. How they collaborate within the group to undergo inquiry-based learning?

I answer the above questions by exploring the student artifacts produced from a collaborative inquiry-based learning conducted in a class of engineering undergraduates. My work may contribute disciplinary-specific examples and provide reference cases for the learning scientists.

Methods and Data Sources

The participants were 124 engineering undergraduates (104 males, 20 females) at the second to the third year (70 second year students, 54 third year students). They took a course for computer simulations and system modeling. These participants formed into groups of 3 to 5, and were engaged a collaborative-inquiry project about capacity sizing for an imaginary trading system. The students formed into 32 groups according to their own preference. Groups with more than half of the members having achieved G.P.A. of 3.5 or above are identified as expert groups. Based on this criterion, 6 out of the 32 groups were identified as expert groups; these groups involved 24 students (19% of all participants, 21 boys and 3 girl). The author admits that such selection criterion is not scientific enough. As a remedy, the two groups were further compared in terms of final examination scores in the course. The final examination was an individual assessment of students' overall learning and its assessment was independent of the project. Students in the expert groups ($M = 83.00$, $SD = 1.93$) different from their counterparts ($M = 64.47$, $SD = 11.11$) significantly ($p < .05$) in terms of final examination performance. Rather then naming the rest of the class as novice group, I refer them as the non-expert groups in the rest of this paper. The participants were required to submit project deliverables that document all planning, findings, and reflections along the project learning process as detailed as possible. Such deliverables reflected how students collaboratively tackled and understood the design problems.

Results

I compared the artifacts of the expert groups with that from the rest of the class. In accordance to the perspectives reviewed in (Bereiter and Scardamalia, 1993; Bruer, 1993; Chi *et al.*, 1981; Chi, Glaser & Rees, 1982), the following characteristics about how experts learn through collaboration and inquiry are identified.

1. Expert groups practiced progressive problem solving while most of their non-expert counterparts adopted the best-fit strategy.
2. Expert groups held knowledge-building goals and demonstrated extensive efforts in seeking external but related information.
3. Expert groups approached the problem with underlying principles and do not take in given information as is.
4. Expert groups demonstrated more sophisticated representation and organization of knowledge and concepts.
5. Expert groups adopted contemporary project management principles as strategies for collaboration and inquiry.

Based on the findings from this study, the followings are suggested for possible follow up in the future:

- Although inquiry-based learning and collaborative learning have been recommended as a pedagogy to enhance student learning and knowledge construction, expertlike learners still demonstrate various differences in their collaboration and inquiry process. Aligning to the previous literatures, they behave differently in a number of aspects such as the problem solving behaviors and the organization of knowledge. The findings discussed in the previous section may provide additional information to learning scientists for improving learning with similar settings.
- The current study provides important information about engineering learning and instruction, However, it is remarked that engineering educators should be aware about the prior knowledge that the students possess, and avoid exposing novices to expert models (Bransford, Brown & Cocking, 2000: p.50).
- Findings from the current studies do provide some useful hints on better implementation of constructivist pedagogies in the engineering discipline, as well as other disciplines in general. For example, contemporary project management skills such as better planning, testing, and documentation of the inquiry process, can be introduced to the students. One can also help the students defining project goal and objectives at the beginning of the projects. In particular, my findings also provide information on how expertlike learners work with system design and computer programming, which are the core competencies for engineering students.

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