
AC 2012-5411: COLLABORATIVE INQUIRY INTO FOUNDATION KNOWLEDGE IN COMPUTER ENGINEERING: A CASE STUDY IN HONG KONG

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Collaborative Inquiry into Foundation Knowledge in Computer Engineering: A Case Study in Hong Kong

Abstract

This paper describes the design and implementation of inquiry-based learning (IBL) lessons in Engineering Education at first-year undergraduate level. The teaching and learning took place in an engineering department at a university in Hong Kong. IBL is a kind of constructivist pedagogy in which learners formulate hypotheses and problem-solving strategies by their own, and learn through inquiries into ill-structured problem situation. This paper reviews related educational theories, describes the lesson implementation process. Evaluation, in terms of quantitative and qualitative analysis on data collected from participating students, are also given.

Introduction

Traditional engineering education is often considered as subject domains that merely follow rule-based computation and procedures. Over the recent years, however, rapid changes in the global technology domain have created an emergent need to rethink about how to educate the engineers of next generations^{1,2}. Inquiry-based learning (IBL) is a kind constructivist pedagogy in which learners formulate hypotheses and problem-solving strategies by their own, and learn through inquiries into ill-structured problem situation^{3,4,5}. It is especially suitable for computer education in 21st century, as well as engineering education in general because of the complexity in the knowledge domain which often involves multiple disciplines^{6,7,8}. This paper describes the design and implementation of IBL lessons in a refreshment course offered by an engineering department at a university in Hong Kong in September to December 2010. Related educational theories are reviewed, including (1) constructivism, (2) inquiry-based learning, (3) collaborative learning, and (4) scaffolding. The lessons were implemented as a part of the course, the lesson plans, class schedule and logistic of the course are also briefly described. Quantitative survey data and qualitative feedbacks collected from participating students are also given to serve as evidences and references for effectiveness of student learning. This paper contributes an exemplar for faculty members in computer sciences and related disciplines in engineering. It also provides references for further follow up works.

Review of Educational Theories

This section review the related teaching and learning theories, namely the three paradigms of learning (behaviorism, cognitivism, and constructivism), scaffolding, inquiry-based learning, collaborative learning and higher order thinking.

Behaviorism, cognitivism, and constructivism

Mainstream perspective of teaching and learning has been migrating. Starting from behaviourism in the 50s, to cognitivism in 70s and 80s, we are now in the era of constructivist teaching and learning⁹. Behaviourism is a theoretical perspective in which learning and behaviors are described and explained in terms of stimulus-response relationships. Cognitivists study how learning occurs and how knowledge is constructed within an individual. Nowadays, constructivism becomes the mainstream perspective of

teaching and learning, it suggests that knowledge cannot be delivered directly but to be constructed by the learners themselves.

Scaffolding and inquiry-based learning

Scaffolding is a constructivist construct. It is evolved from Bruner's work¹⁰ and resembles how the physical scaffolds are used to guide the construction of a building. Similar to physical construction, instructional scaffolds only serve as temporary support during the learning process, so that learners can accomplish learning outcomes that they cannot perform on their own ordinarily. To make scaffolding effective, the learning task cannot be too straight forward that learners can quickly finish easily¹¹. Scaffolding is therefore suitable for IBL which often involve non-trivial problems which are open-ended.

In IBL, learners invent new hypotheses instead of investigating problem that are defined by the instructor¹². IBL is an educational approach that helps learner to seek for knowledge and information through asking questions. During the inquiry process, students construct their understanding of the environments. It also emphasizes on the development of an inquiry attitude and the corresponding skills¹³. IBL is not the same as project-based learning and problem-based learning; the former emphasizes the processes of inquiry along the entire project while the later two focus on the development of the ultimate deliverables, or a well defined problem have been provided. Tsankova and Dobrynina⁵ suggested a 3-step procedure for IBL implementation: (1) initiating inquiry, (2) coaching during an inquiry, and (3) assessing inquiry-based learning. (2) and (3) is a feedback process.

Collaborative learning and higher order thinking

Collaborative learning is a social learning model, which evolved from the works of the social constructivists including Vygotsky¹⁴ and Dewey¹⁵. In a collaborative learning environment, learners who are at different levels of performance work together in groups, and achieve toward a collective learning goal. During the collaborative learning process, a set of roles and rules is often developed among the members and they are responsible for one another's learning. Therefore collaborative learning can also foster the development of and the enhancement of the higher-order thinking skills such as critical thinking, problem solving, and team work¹⁶.

Course Design and Implementation

The IBL activities described in this paper is implemented in 4 out of the 12 lessons of a refresher course titled "Information Engineering and the Society". There were 144 students enrolled in total, who were mainly from the Computer Engineering and Information Engineering disciplines. The course has covers three main components: (1) basic knowledge about practices of professional engineers, (2) theoretical knowledge in information engineering, and (3) introduction to technologies in information engineering. In particular, IBL activities have been designed and conducted in the teaching and learning of the third component. 4 lessons were carried out to implement the teaching.

Students were divided into groups of 6 members, while there are 24 groups altogether.

4 different topics were taught in the 4 lessons respectively. They were:

1. Flow control in networks
2. Signal processing
3. Information and network security; and
4. Applications of information engineering in the society

Although these topics seem disjoint among themselves, each of them is connected to the overall programme curriculum. We describe the general design of the 4 lessons according to the three-step model described in previous section as well as in¹⁷.

Initiating inquiry

Prior to the inquiry process, a problem as well as the related information is released to the learners. The expected deliverables are also specified. But the procedures for solving the problem were not given. For example, in the lesson for Information Security, a case which described an online bookstore with clients complaining about stolen account and unauthorized transactions were given, and students were asked to investigate into the possible causes, and proposed corresponding solutions.

Coaching during an inquiry

After the problem and the expected deliverables are clearly explained, the inquiry process can then begin. In the lessons, learners conduct inquiry collaboratively in groups, they fully analyze and comprehend the problem, plan how to investigate, and summarize and reflect on the results. Scaffolding aid is critical in this step and is provided in terms of short lecture, reference web sites, hands-on experiments, and guided activities. These scaffoldings were provided with the principle that no direct answers or solution to the overall problem were released. Semi-structured templates were also given to students to scaffold them in constructing the final solutions. Figure 1 shows a semi-structured worksheet with scaffolding information and hands-on experiments which used to guide the learner's inquiry process about the topic in Signal Processing.

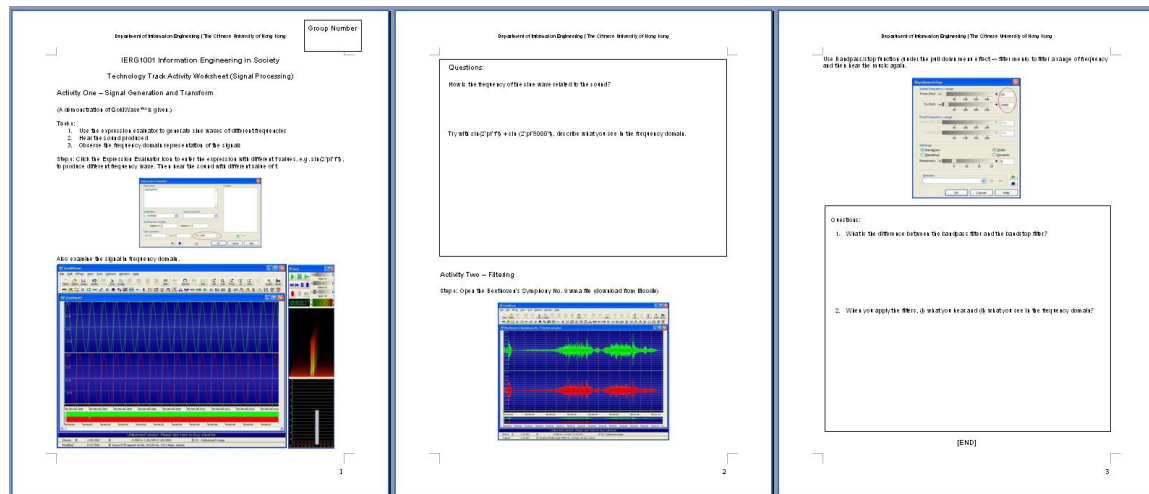


Fig. 1. Worksheets that provide scaffolding aids to guide the inquiry process in Signal Processing.

Assessing student learning

Learners were informed at the beginning about how their learning would be assessed. As suggested by Tsankova and Dobrynina⁵, the IBL assessment was driven by the inquiry process. Feedback was also provided to the learners in order to help improving the quality of ongoing inquiry. The learners submitted deliverables at different stages, at intermediate stages, formative assessments were made. They were given immediate feedbacks and comments.

Format of deliverables for assessments in the described course include: semi-structured report, production of presentation slides, posters, as well as video clips to be posted online.

Collaborative learning

As reviewed in previous section, collaborative learning enable learners who are at different levels of performance to work together in groups, and achieve toward a collective learning goal. In the lessons, students were divided into group of 6. The groupings were arranged by the instructor. In addition, each group included a mixture of learners with different background, e.g. students from China were mixed with those from Hong Kong, and students from Computer Sciences and Engineering were mixed with those from Information Engineering.

According to learning principles¹⁶, by learning collaboratively, group members can have their higher-order thinking skills enhanced and fostered, including those in critical thinking, problem solving, and team work. Figure 2 gives a snap shot of group discussion (left) and student presentation (right) during the lessons.



Fig. 2. During the IBL lessons, students conducted collaborative learning, snapshots of group discussions during class (left) and group presentation (right).

Evaluation

This section provides quantitative and qualitative evaluation, and discusses about the IBL implementation. Two data sources are adopted in evaluating the effectiveness of students' learning:

1. A questionnaire adapted from Hofer's instrument on personal epistemology¹⁸ (with contextualization in fundamental computer engineering knowledge as the subject) to assess participants' epistemological beliefs before and after the course.
2. Reflective essays submitted by the students at the end of the course, which describes about their learning process.

The questionnaire consists of 18 items, measuring students' epistemological belief in four dimensions: certainty (8 items), justification (4 items), source of knowledge (4 items), and attainment of truth (2 items). We refer the readers to¹⁸ for detail elaborations on these dimensions. A number of learning theorists advocated that part of the goal of education is to foster epistemological development^{19,20,21,22,23}. Therefore, we evaluating student learning in terms of epistemological belief change.

Quantitative Results

The Cronbach's alpha coefficients for the 4 scales were .69 (Certainty), .63 (Justification), .61 (Justification), and .64 (Attainment of truth). These values indicate acceptable data reliability. Analyses were conducted to investigate whether differences existed regarding epistemological beliefs by gender and original residence (mainland or local). The 2 (gender) \times 2 (residence) ANOVA did not yield any significant main effect.

Paired-samples *t* test on each of the four dimensions were conducted with effect size (Cohen's *d*) indicated, where conventionally values of .20, .45, and .75 are regarded as small, medium, and large effect size, respectively²⁴. Significant differences between pretest and posttest scores were found in three measures: Certainty [$t = 4.90$, $d = .43$, $p < .001$] with lower score in posttest ($M = 21.24$, $SD = 5.52$) than pretest ($M = 23.53$, $SD = 5.09$), Justification ($t = -4.34$, $d = .49$, $p < .001$) with higher score in posttest ($M = 12.79$, $SD = 2.57$) than pretest ($M = 11.51$, $SD = 2.64$), Sources [$t = 4.15$, $d = .42$, $p < .001$] with lower score in posttest ($M = 12.57$, $SD = 2.43$) than pretest ($M = 13.68$, $SD = 2.79$). Attainment of truth [$t = 1.53$, $d = .14$, $p > .05$], however, did not reflect any significant difference between pretest ($M = 6.18$, $SD = 1.87$) and posttest ($M = 5.94$, $SD = 1.65$). The results are presented in Figure 3.

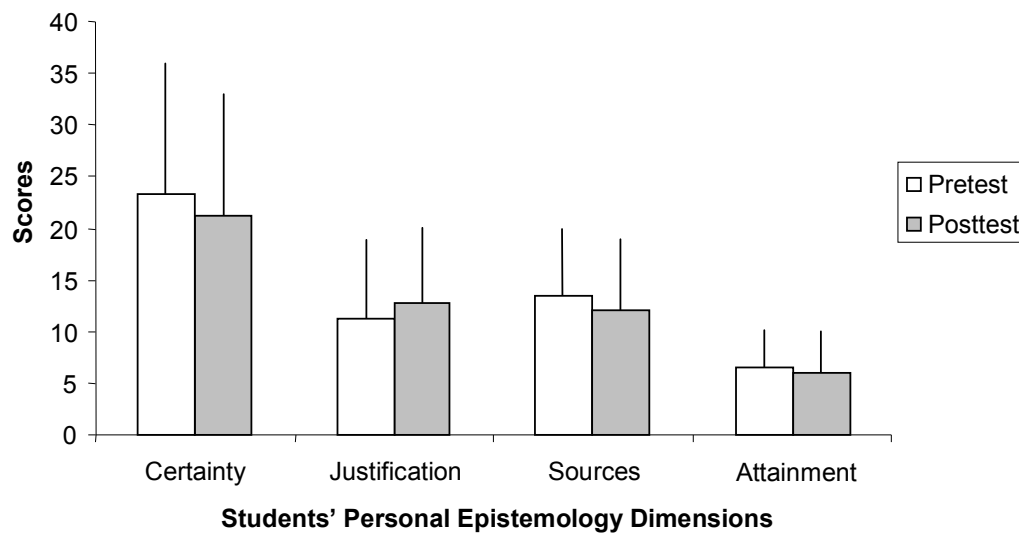


Figure 3. Pretest and posttest scores on the 4 personal epistemology dimensions. 18 questionnaires items in fundamental computer engineering knowledge contexts, adapted from (Hofer, 2000).

Learning can be influenced by the epistemological beliefs held by individuals. For example, student performance was negatively correlated with belief in simple knowledge; those who viewed knowledge as certain were likely to generate absolute conclusions that were inappropriate²⁵; personal epistemology also plays a role in self-regulated learning²⁶; belief about knowledge as certain and simple was found to be negatively correlated with conceptual change learning²⁷; scientific arguments, in combination with constructivist epistemic beliefs, would produce greater learning about physics concepts²⁸. Our empirical results showed that after the inquiry-based learning process, participants regarded knowledge as less certain and absolute. They were less likely to regard personal knowledge as a basis for justification of knowing. They also viewed authority less as a source of knowledge. These indicate the students have moved towards a more sophisticated belief in knowledge, influencing their learning in a favorable way. However, the participants did not change their view about the attainment of truth by experts.

Qualitative Results

A student described about the IBL activities that she has gone through, and expressed her positive view about this teaching and learning approach:

In these lessons, professors taught something about network communication and information security. I have some basic knowledge about these areas, but I only learned these from books and lecturers. In these lessons, we had interactive actions to let us know the theory behind and then professors gave detailed explanation, which make these theories and knowledge more memorable.

Another student wrote about the IBL pedagogy, and commented that IBL helped him constructed knowledge as the subject contents were not taught directly but was to be constructed by the students on their own:

The professors and tutors will not teach us anything but help us to learn. We have to learn things and find the answers of our questions by ourselves and translate them to become our knowledge. Therefore, learning with this teaching method help me to understand how to obtain knowledge efficiently. Discussing with others and asking questions are some other ways that can help learning but not only listen from others.

Student also expressed gains from social interactions in group collaborations, including helping each others and practicing Putonghua (as there were a mixture of students from China and Hong Kong in each group):

I'd try my best explaining what they don't understand in the course, and they did a lot helping me catch up and practicing their mandarin in order to communicate well with me and another mainland boy (although not much progress has been made :D). They are also very grateful for everyone else's work.

However, there were also limitations and rooms for further improvements. For example, a student pointed out that the time for learning software during the lesson (lab) is not enough:

In addition, it may be because the time is not enough, the introduction of those software used in the lab is too short and a bit rush.

The above are extracts from randomly selected feedbacks from students. Overall, students find the teaching and learning method in this course innovative and novel. Most of them preferred IBL over traditional teaching method and expressed that they could construct knowledge by their own and learn deeper with IBL approach. They also enjoyed and appreciated the interactions with their group members in the collaboration.

Concluding Remarks

In this paper, design and implementation of IBL lessons in Computer Education contexts had been described and discussed. Related educational theories were reviewed, with implementation process described. Evaluation of the implementation had been performed by analyzing quantitative measurements on students' epistemological belief change, as well as qualitative feedbacks collected from the students. Overall, students find IBL innovative and novel. They also preferred IBL over traditional teaching method. They also gained from the group interactions in collaborative learning. It is also found that the implementation promote students' epistemological belief change in a number of dimensions.

The case presented in this paper can serve as a reference for potential IBL implementation in Electronic and Computer Engineering Education, especially in refresher courses. Although the current work is a one-time investigation, follow up studies can be made to detect the long term effect of IBL experience on students' engineering learning at a more advanced level. For example, longitudinal data on students' academic performance can be collected and compare with their reflection about the IBL experience, so as to study the long term impact of IBL-based refreshment course on students' learning.

Bibliography

1. Chan, Y.-Y., Chan, C. K. K.: Engineering Undergraduates Learning Computer System Modeling in a Constructivist Learning Environment: Multi-Level Analysis of Collaborative and Individual Learning. America Educational Research Association Annual Convention 2010 (AERA 2010), Denver, CO. (2010)
2. National Academy of Engineering (NAE). The Engineer of 2020, Visions of Engineering in the New Century. National Academy Press, Washington, DC. (2004)
3. Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T.: The role of inquiry in science education: Analysis and recommendations. *Science Education* 65, 33—50 (1981)
4. Bloom, L. Z. & White, E. M.: Inquiry: a cross-curricular reader. Englewood Cliffs (ed), Prentice-Hall, Inc. NJ. (1993).
5. Tsankova, J. and Dobrynina G.: Developing curious students. Integrating Inquiry across the Curriculum, 85—109, Corwin Press, Thousand Oaks, CA. (2005)
6. LaPlaca, M. C., Newstetter, W. C., Yognathan, A. P.: Problem-based learning in biomedical engineering curricula, In Proceedings Frontiers in Education Conference 2, F3E-16-21. (2001)
7. Froyd, J. E. Ohland, M. W.: Integrated engineering curricula, *Journal of Engineering Education*, 94(1), pp. 147-164, (2005)
8. Chan Y.-Y., Yu A. C. H., Chan C. K. K.: Assessing Student Collaboration and Learning in Medical Engineering from the Perspectives of Structures, Behaviors, and Functions, ASEE-IEEE 40th Frontiers in Education Conference (FIE 2010), SIG, Washington DC. (2010).
9. Ormrod, J. E. Educational psychology: Developing learners (5th edn). Pearson Education, Upper Saddle River, NJ. (2006)
10. Bruner, J. S., Toward a Theory of Instruction. Harvard University Press, Cambridge, MA. (1966)

11. Peterson, C., Caverly, D. C., MacDonald, L.: Developing academic literacy through WebQuests, *Journal of Developmental Education*, Vol 26, No 3, pp.38-39. (2001)
12. Chan, Y.-Y. Teaching Queueing Theory with an Inquiry-Based Learning Approach: A Case for Applying WebQuest in a Course in Simulation and Statistical Analysis. In *Proceedings of the 37th IEEE/ASEE Frontiers in Education conference*, (F3C-1-6), Milwaukee, WI. (2007)
13. Educational Broadcasting Corporation. <http://www.thirteen.org/edonline/>.
14. Vygotsky, L.: The socialist alternation of man. *Journal of the All-Union Association of Workers in Science and Techniques for the Furthering of the Socialist Edification in the USSR*. (1930) (Original text in Russian Language)
15. Dewey, J.: *How We Think: a Restatement of the Relation of Reflective Thinking to the Educative Process*. Boston: Heath. (1933)
16. Gokhale, A. A.: Collaborative learning enhances critical thinking," *Journal of Technology Education*, 7(1). (1995)
17. Chan, Y.-Y., Lam, H. F., Yang, H. H. et al. : Hybrid Inquiry-based Learning, *Handbook on Research on Hybrid Learning Model*, Information Science Reference. (2010)
18. Hofer, B. K: Dimensionality and Disciplinary Differences in Personal Epistemology, *Contemporary Educational Psychology*, 25, 378 – 405. (2000)
19. Baxter Magolda, M. B. (1992). *Knowing and Reasoning in College: Gender-Related Patterns in Students' Intellectual Development*, Jossey Bass, San Francisco.
20. Hofer, B. K.: Personal epistemology research: Implications for learning and teaching. *Journal of Educational Psychology Review*, 13(4), 353 – 383. (2001)
21. King, P. M., and Kitchener, K. S. *Developing Reflective Judgment: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults*, Jossey-Bass, San Francisco. (1994)
22. Perry, W. G.: *Forms of Intellectual and Ethical Development in the College Years: A Scheme*, Holt, Rinehart and Winston, New York. (1970)
23. Schraw, G. & Sinatra, G. M.: Epistemological development and its impact on cognition in academic domains. *Contemporary Educational Psychology*, 29, 95 – 102. (2004)
24. Vacha-Haase, T. and Thompson. B.: How to Estimate and Interpret Various Effect Sizes, *Journal of Counseling Psychology* 51: 473-481. (2004)
25. Schommer, M.: Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, 82, 498–504. (1990)
26. Garrett-Ingram, C. Something to believe in: The relationship between epistemological beliefs and study strategies, Paper presented at the American Educational Research Association, Chicago, IL. (1997)
27. Qian, G., & Alvermann, D.: Role of epistemological beliefs and learned helplessness in secondary school students' learning science concepts from text. *Journal of Educational Psychology*, 87(2), 282 – 292. (1995)
28. Nussbaum, E. M., Sinatra, G. M., and Poliquin, A.: Role of epistemic beliefs and scientific argumentation in science learning. *International Journal of Science Education*, 30(15), 1464-5289. (2008)