Direct Evidence of Engineering Students' Generic Skills Learning:

From Research to Practice in an Undergraduate Course in Information Engineering

Rosanna Yuen-Yan Chan[1], Cecilia Ka Yuk Chan[2], Carmen Lau[3],
Jiaxin (Jonathan) Liang[1], Huaiyi Huang[1], Qi Cao[1], Mehrdad Tahernia[1]
[1]Department of Information Engineering, CUHK
[2]Centre for the Enhancement of Teaching and Learning, HKU
[3]Centre for Learning Enhancement and Research, CUHK
Hong Kong SAR

***Abstract*—There has been a growing attention to engineering graduates' generic skills competency. Generic skills attainment is included as essential graduate attributes by accreditation bodies such as Accreditation Board for Engineering and Technology (ABET). Generic skills competency is often assessed at program level using indirect measures such as graduate surveys and student interviews. In this work-in-progress, we present the design, collection, and analysis of direct and indirect evidences of engineering students' generic skills learning at course level. In particular, we report an on-going implementation case study in a course for engineering undergraduates. Our study is rooted in the theoretical framework of social epistemic cognition which explains knowledge acquisition in social contexts. We also discuss our preliminary results collected from the online learning community participated by all students in the course (direct evidence) and a survey on the participants' beliefs associated to social epistemic cognition and collaborative learning (indirect evidence).**

Keywords—assessment; direct evidence; indirect evidence; generic skills; social epistemic cognition

I. INTRODUCTION

A growing emphasis is being placed on engineering graduates' generic skills by accreditation bodies, employers, and also engineering students and teachers [1]–[5]. Engineering education practitioners demand for research results that can inform about the collection and analysis of evidence in students' generic skills learning. Indirect evidence such as questionnaires and interviews are often used to measure student generic skills competency. However, indirect assessment may not be as reliable as direct assessment since the former is self-reported and retrospective [6]. On the other hand, direct evidence such as students' written work scored with a rubric can offer learning data that directly answers the assessment questions. However, the use of direct evidence as a measurement of engineering student generic skills learning is still at an early stage (see [7] for a very recent work contributed by the second author). Nevertheless, a few related works have been identified. For example, Barr, Krueger, and Aanstoos [8] presented a case in which direct evidence (team project reports) as well as indirect evidence (learning outcome assessment survey) of student learning in a mechanical engineering course was collected and analyzed. Weldy and Turnipseed [9] also performed a study on business school students in which management projects were used as a pedagogical tool, with survey on students' perception of learning (as indirect evidence) and their actual learning measured using rubrics (as direct evidence) compared.

The purpose of this work-in-progress study is to provide and analyze direct evidence of students' generic skills learning within an undergraduate engineering course. Our study is supported by the theoretical framework of social epistemic cognition. This work directly addresses the measurement of ABET student outcomes regarding multidisciplinary teamwork (d) and life-long learning (i). We contribute systematic procedures for the collection and analysis of direct evidence in students' generic skills learning in an engineering education context.

II. PRELIMINARIES

A. Generic Skills Competency in Engineering Education

Generic skills are "skills, abilities and attributes which are fundamental in helping students to acquire, construct and apply knowledge" and "are generic to different learning situations" [10]. In other words, generic skills are those that "help students learn how to learn" [11]. Nine types of generic skills have been identified, namely (1) collaboration skills, (2) communication skills, (3) creativity skills, (4) critical thinking skills, (5) information technology skills, (6) numeracy skills, (7) problem-solving skills, (8) self-management skills, and (9) study skills (p.35). Furthermore, since these skills are generic in nature, they can be overlapped with each other. Generic skills learning and acquisition also need to go together with a student's values and attitudes development (p.36). Over the recent years, governments and organizations worldwide have begun to promote the strategic importance of generic skills [1]–[5]. Engineering education accreditation bodies such as the Accreditation Board for Engineering and Technology (ABET) and International Engineering Alliance (IEA) have included the attainment of generic skills as essential graduate attributes [12], [13]. The engineering education research community has also begun to develop theory grounded instruments for measuring engineering students' belief associated to generic skills competency [7].

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B. *Direct and Indirect Evidences of Student Learning*

As Palomba and Banta suggested, assessment can be a systematic collection, review, and use of education information for the purpose of student development and learning improvement [14, pp.4]. Student learning assessment can involve direct and also indirect evidences. While indirect evidence (such as end-of-course evaluation, assignment grades without a rubric) offers signs that suggest students are probably learning, direct evidence gives tangible and compelling indication that show what students have learned [6]. Examples of direct evidence of student learning include learning portfolios, written work scored with a rubric, observations of student behaviors in classroom and online discussion forums, etc. [15] Although direct evidence provides more reliable information about student learning, many challenges may occur in its collection. Nevertheless, it is emphasized that direct and indirect evidences can supplement each other. While the former tells explicitly what students have learned, the later is more related to students' attitudes and beliefs along their process of learning (see e.g., [14, Ch.2]). Therefore direct and indirect evidences can be used to explain and support findings obtained from each other.

C. *Social Epistemic Cognition and Its Implication on Direct Evidence Collection*

Social epistemic cognition (SEC) is a tripartite theoretical framework rooted in philosophy (social epistemology) [16], psychology (social cognition) [17], and education (applied epistemic cognition) [18]. The first author of this paper has presented a proven theory in human-computer interaction that SEC can be mediated by online interactions [19, pp.3296]. The SEC conceptual framework suggests that student internal beliefs associate to knowledge and knowing can be explained and observed by external behaviors e.g., the use of epistemic vocabulary in social interactions such as online discourse construction. Content analyses have been conducted over online discussion forums, ranging from small data, single course scale to big data, massive online open course (MOOC) scale; with results respectively indicating that SEC is related to learners' epistemic beliefs, social network behaviors, and academic performance (see [20], [21]). Situated in the SEC theoretical foundation, the current study aims at collecting direct and also indirect evidences of engineering students' generic skills learning at course level.

III. THE CURRENT STUDY

A. *Teaching and Learning Context*

This study was conducted in a course for undergraduate engineering students, "Social Media and Human-Information Interactions". It was implemented (for the first time) in the spring semester of 2017. The course was designed and taught by the first author and was supported by the last four authors as teaching assistants. The course is multidisciplinary in nature and aims to enable students to understand about social media and the interaction between human and information. It covered conceptual knowledge and also practical knowledge related to theories, models, analysis, and visualization techniques in social media and human information interactions (figure 1).

B. *Collaborative Learning Process and Assessment*

Two of the learning outcomes that the course delivered were directly related to generic skills learning:

1. an ability to function on multi-disciplinary teams; which was adopted from ABET student outcome (d); and
2. an ability to recognize the need for, and to engage in life-long learning; which was adopted from ABET student outcome (i).

In addition to traditional regular lectures, a class blogger community was established among all students enrolled in the course. In particular, every student was required to maintain an e-portfolio (in form of a blog site with at least 4 posts) to reflect about their own learning. Guidelines about portfolio writing and scoring rubric were provided to the students. The students were also encouraged to actively comment on each other's blog posts. These online activities yield two out of the five assessment items in the course (see figure 1 below).

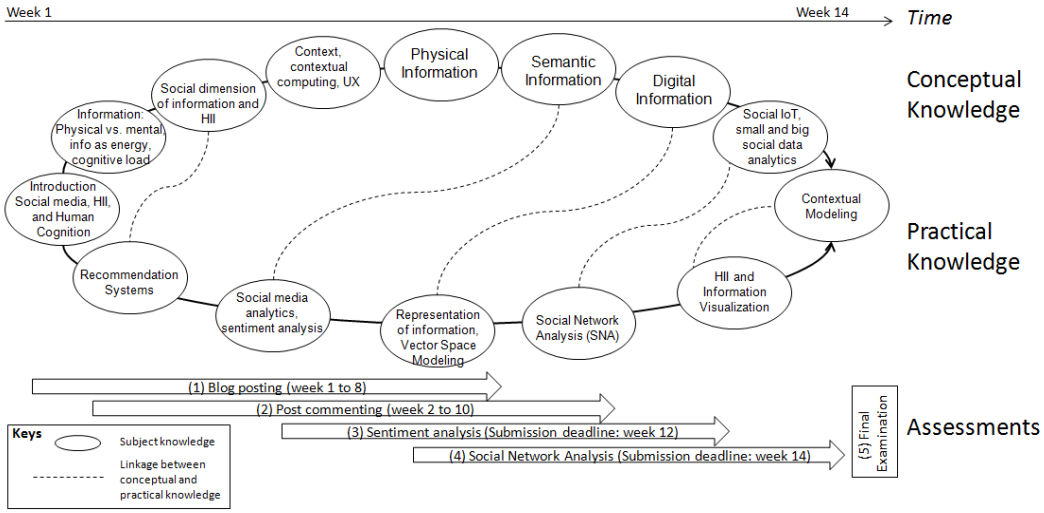

Fig. 1. Overall schedule for course teaching, learning, and assesment (14 weeks). Students were required to complete 5 assessment items: (1) blog posting, (2) post commenting, (3) sentiment analysis on post comments, (4) social network analysis on the class blogger community, and (5) final examination.

The current study aims to define, collect, and analyze direct as well as indirect evidences of engineering student generic skills learning at course level. It is rooted in the conceptual framework of SEC and is guided by three research questions. They are:

1. (RQ1) How SEC conceptualizes students' efficacy in generic skills and what are the possible direct and indirect evidences in measuring it?
2. (RQ2) To what extent are the direct and indirect evidences related to each other?
3. (RQ3) What new direct (as well as indirect) evidence on engineering students' generic skills can we obtain from this study to inform about engineering education practices?

IV. METHOD

A. Participants

Participants were 78 engineering students enrolled in the course IERG3320 Social Media and Human Information Interactions offered by Department of Information Engineering, the Chinese University of Hong Kong during the spring semester of 2017.

B. Procedures

The study took place in the context of the course. In addition to attending regular lectures, the students socially interacted in a blogger community through publishing blog posts and commenting on each others' post contents. A total number of 78 blog sites have been established by the participants over a 4-month implementation period during January to April 2017. A social network was established among the students through their online interactions.

C. Measures

The following direct and indirect evidences which measure students' generic skills were collected:

1. **(Direct evidence)** Blog post contents (as e-portfolios) which include students' own learning reflections and self-collected external reference materials.
2. **(Direct evidence)** Online comments which reflect students' evaluation on their peers' learning reflection.
3. **(Direct evidence)** Topological structure of the resulted online social network.
4. **(Indirect evidence)** Questionnaire on students' beliefs associated to SEC [19] and collaborative learning [22].

Table 1 provides the schedule of evidence collection.

TABLE I. DIRECT AND INDIRECT EVIDENCE COLLECTION

Measurement Item	Time of Collection
Students' beliefs associated to SEC and collaborative learning prior to the course (pretest questionnaires)	Week 2
Students' self-reflection of learning and self-collected external materials (blog post contents)	Week 1 to 8
Students' evaluation on peers' learning reflection (as online comment contents)	Week 2 to 10
Topological structure of the blogger social network	Week 10
Students' beliefs associated to SEC and collaborative learning at the end of the course (posttest questionnaires)	Week 14

Students' blog posts were scored using the scale given in table 2. It is developed according to Biggs' Structure of the Observed Learning Outcomes (SOLO) taxonomy [23]. The scoring scale is also available to the participating students.

TABLE II. SCORING SCALE OF BLOG POST CONTENTS

Level	Description
4	Ability to apply the subject knowledge learned in the course in novel ways. Be able to communicate the synthesized ideas or application clearly and convincingly.
3	State and apply the subject knowledge learnt in the course to typical situations in a logically related way.
2	Enumerate, describe, and/or list multiple unrelated points.
1	State, recognise, recall, and tell on a single point.
0	Missing the point.

V. PRELIMINARY RESULTS

The current work is an on-going study. While the entire teaching, learning, and assessment process has not been completed, preliminary results that have been obtained so far include: (1) social network analysis metrics of the resulted blogger community (direct evidence); and (2) pretest and posttest scores on students' beliefs associated to SEC and collaborative learning (indirect evidence).

A. Social Network Analysis (Direct Evidence)

In the end of the course, a blogger social network which is a directed graph with 78 nodes and 1105 edges was established. The nodes correspond to the participating students; and each of the directed edge represents a "comment to" relationship between a comment provider and a comment receiver. Two social network metrics, in-degree (M = 9.26, SD = 4.64) and out-degree (M = 9.24, SD = 4.59) of each of the participants were calculated. Figure 2 below shows the time series of the sociogram in 6 time intervals.

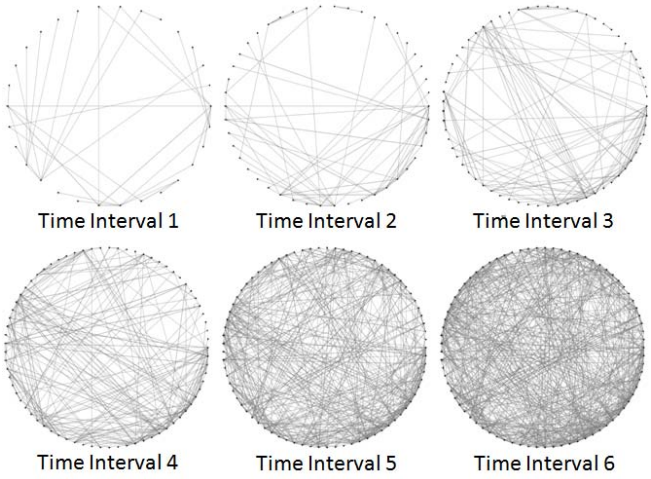

Fig. 2. Development of the class blogger community over time.

B. Student Beliefs Associated to SEC and Collabortaive Learning (Indirect Evidence)

Table 3 provides the descriptive statistics for the measurement of students' beliefs associated to SEC and collaborative learning (pretest and posttest scores). The

means were obtained from the average scores of items within a same scale (e.g., social epistemic aim) (see [18] and [21]). Cronbach's alpha values for pretest and posttest items are 0.87 and 0.80, respectively; which indicate high reliability.

TABLE III. DESCRIPTIVE STATISTICS OF SEC AND CKB SCALES

Scale	Pretest M (SD)	Posttest M (SD)
Social epistemic aims (6 items)	3.72 (0.72)	4.03 (0.70)
Structure of knowledge (6 items)	3.90 (0.52)	4.06 (0.71)
Justification of social knowledge (7 items)	3.93 (0.57)	3.97 (0.65)
Social epistemic virtues (7 items)	3.68 (0.65)	3.93 (0.64)
Processes of achieving aims (6 items)	3.87 (0.56)	3.95 (0.65)
Collaborative learning (12 items)	3.98 (0.54)	3.82 (0.88)

C. Relationship between Learning Beliefs and Behaviors

A significant relationship between SEC gains and social networking behavior was identified. In particular, participant out-degree was significantly correlated to belief gains in justification of social knowledge ($r = .44$, $p < 0.05$) and social epistemic virtues ($r = .41$, $p < .05$), respectively.

VI. DISCUSSION

A. Conceptualization of Students' Generic Skills Efficacy and Online Behaviors with Social Epistemic Cognition

The social dimension of generic skills is particularly related to SEC as the latter explains a student's intention to socially interact with his or her peers in achieving epistemic aims such as co-construction of new knowledge. Meanwhile, problem solving and teamwork in engineering learning often involve reliable processes of achieving social epistemic aims within a collaborating group ([18, p.159], [19]). As observed in the current study, student exercise their argument skills in the blogger community to present their views to their peers. Moreover, a more sophisticated recognition of the structure of social knowledge (e.g. whether it is multidimensional or stochastic [18, p.150]) is likely to promote a student's intention to conduct interdisciplinary and life-long learning. In the blogger community that we studied, it was observed that some students searched for online resources that had not been covered in the lecture and shared them with their fellow classmates in their blog posts).

B. Relationship between Direct and Indirect Evidence of Student Generic Skills

As inherits from Goldman's social epistemology framework [16], SEC suggests that students' internal beliefs associate to epistemic matters can be represented by externally observable social evidence such as online discourse [16, Ch.1]. Our preliminary results show that students' gain in SEC (namely, the justification of social knowledge and social epistemic virtue components) is significantly related to the level of participation in the class blogger community (as measured by the out-degree in the resulted social network). In our implementation case, students' SEC belief gains (as indirect evidence of generic skills learning) and level of online social networking activities (as direct evidence of generic skills learning) were found to be significantly correlated to each other.

C. Implication to Engineering Education Practice

The current study takes an early departure in using social network analysis metrics of an engineering class blogger community as direct evidence to measure the ***social dimension*** of generic skills learning. More specifically, our measurements addressed graduate attributes in existing accreditation standards namely student outcomes (d) and (d) in the ABET accreditation criteria [12]. We have also described the systematic procedures in collecting and analyzing the direct evidence (i.e. the establishment of the class blogger community and the report of social network analysis metrics); and proved the significant relationship between direct and indirect evidences. Furthermore, our assessment design is rooted in the SEC theoretical framework [19], which in turn is supported by a solid foundation in social epistemology [16], social cognition [17], and epistemic cognition [18] that inform about students' knowledge and knowing within a social context.

D. Limitations, On-Going Work, and Future Work

We acknowledge a few limitations in this work-in-progress. First, the study has only been conducted in a single implementation of a course with limited sample size. Second, students' overall academic achievements in the course have not been measured as of the date of the completion of this article. As on-going work, we will complete our analysis with a full set of assessment data collected from the current course. We will also repeat the study in future implementation of the same course and also in other engineering courses (especially those that are more traditional such as those for electric circuits and wireless communications).

VII. CONCLUSION

We have presented the collection and analysis of direct evidence in engineering students' generic skills learning. Through establishing a class blogger community, we showed that social network analysis metrics could be used as direct measures of engineering student generic skills attainment. We showed a significant relationship between our direct and indirect evidences. Our assessment items addresses the student outcomes within existing accreditation standards such as that in ABET. We hope this work-in-progress can engender further discussions about direct evidence of engineering students' generic skills learning within and beyond the engineering education community.

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