Gaining an Insider Perspective on Learning Physics in Hong Kong

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Abstract: This study provides an exploration of physics teaching and learning in a classroom in Hong Kong. The goal of the study was to understand how to develop Bereiter and Scardamalia's knowledge building approach for Asian contexts in away that is sensitive to Asian values. The paper reviews some aspects of learning physics in Asia from a Confucian-heritage perspective, and then reports a case study of physics learning with Knowledge Forum. Participants were 82 Form 4 (Grade 10) students taking two successive versions of a physics course. Data collected included classroom observations, measurement of physics learning, reflection, epistemic beliefs, attitudes toward science, and use of Knowledge Forum. The findings open up a number of questions for further research.

Introduction

Work in classrooms based on the major educational approaches produced by the learning sciences is still at an early stage in Asian contexts, particularly approaches that make extensive use of collaboration, inquiry, and classroom discussions. However, to advance from this position does not merely involve *adapting* Western approaches to Asian contexts, which may lead to misinterpretations of how learning occurs there (Biggs, 1996). Rather, the premise of this paper is that it would be useful to develop an insider perspective on the learning sciences, based on a study of the values underpinning educational practices, review of research on Asian classrooms, extensive classroom observation, and a critical examination of perspectives from the learning sciences. With an insider perspective, we may then develop educational approaches in ways that build on Asian values and accomplishments, without inflicting what Ann Brown called "lethal mutations" (Brown & Campione, 1996).

This paper reports on a two-year exploration of this kind focusing on the teaching and learning in two successive Physics courses (Form 4 or Grade 10) taught by the same teacher; the context for this exploration was a research program on knowledge building (Scardamalia & Bereiter, 2006). The researcher reviewed the literature on cultural influences on science education in Confucian-heritage countries (mainly China, Korea, Japan, Taiwan, Singapore, and Malaysia), used ethnographic methods to observe classes, and measured wide range of variables thought to be relevant to knowledge building. Assessments measured physics knowledge, reflection on knowledge, attitudes towards science, and epistemic beliefs. Assessments of physics knowledge included capabilities considered important by the Physics Education Research (PER) community—detailed knowledge of concepts, and ability to develop explanations that refer to physics principles and causal mechanisms. The goal of the paper was to *benchmark* performance by the classes studied against international studies of physics learning and knowledge building, and to gain an understanding of how to evolve the knowledge building approach. Suggestions for development are outlined in the conclusion section.

Cultural Considerations

External examinations are important in the West and influence teaching, but they have far greater cultural significance in the East. From the Han Dynasty (206 BC-220 AD) to the end of Imperial China, the *Keju*, a set of government examinations was used to select people from all walks of life for government positions (Amano, 1990). Preparing oneself for these examinations involved years of effort and commitment, but when a person passed them it led to upward social mobility and was a matter of great pride and advantage for their family. As an ancient Chinese idiom states, "Although studying anonymously for 10 years, once you are successful, you will be well-known in the world." The influence of Confucianism has decreased throughout the 20th century, but the emphasis on effort and accomplishment and their relationship to honor and social mobility have endured, producing societies that remain more hierarchical than in the West. Scholars have observed that moral self-perfection and social development are the most important educational goals, ahead of intellectual achievement (Gao, 1998; Lee, 1996; Li, 2009). Lau and colleagues concluded from a recent study of management issues in science classes in China, Israel, and Australia that Chinese teachers were more likely to mention that "learning to respect authority was a significant outcome of education" (see Lewis, Romi, Qui, & Katz, 2005, p. 731).

In present-day Hong Kong, students present themselves for the Hong Kong Certificate of Education Examination (HKCEE) at the end of Form 5 (Grade 11). Consistent with the above cultural influences, these examinations have a high standard. For example, of 29,713 students taking the 2008 Physics examination, only 4.6% received an 'A', 30.4% between 'A' and 'C', and 77.6% any passing grade (Hong Kong Examination and Assessment Authority). HKCEE results are very important for social mobility. Many employers require at least five passes for clerical positions, and HKCEE results are taken into consideration, besides university results, in applications to postgraduate programs. Standards in other Asian jurisdictions are similar. In a study of Chinese

teachers (Gao & Watkins, 2002), one teacher commented that performance on matriculation examinations is "the most important even the only aspect by which the school assesses my teaching" (p. 65). These authors assert: "If the performance of students is not as good as expected, their teachers, principals and the head of the local government education department are all punished" (p. 71). Clearly, in implementing innovative educational approaches, teachers cannot afford to jeopardize examination results. Although in Hong Kong substantial curriculum and assessment reforms are in progress, there is no evidence that the high standards will be adjusted.

These conditions have a profound impact on classrooms. For example, Gao (1998) found that in China many teachers teach a three-year physics course in two years, reserving the final year for review and practice for the examination. Teachers may also schedule extra lessons and homework during school vacations. These practices are used because although daily teaching focuses on understanding of physics, this is not thought to be sufficient for the level of precision and detail at which students are examined. Asian teachers prefer didactic approaches, but disagree these are teacher-centered. One Chinese teacher interviewed by Gao and Watkins (2002) said, "If the teacher focuses on encouraging students, setting questions to challenge them, directing them to explore new knowledge, I don't think that means teacher-centered" (p. 73). Chinese teachers also say that classroom learning is not the whole of student learning, that after class student learning becomes more active (Gao, 1998). Several studies conclude that Taiwanese students have few opportunities to discuss their ideas in class (Aldridge & Fraser, 2000; Wallace & Chou, 2001). Aldridge and Fraser refer to a 1984 study on child rearing in Hong Kong, which concluded that attitudes towards filial piety (respects for one's parents and ancestors) was correlated positively with strictness and discipline and negatively with the expression of opinions and independence (p. 214). According to some scholars, Chinese students prefer to learn (comprehend) new material before raising questions about it and discussing it with others (Li, 2009).

Nevertheless, pedagogical approaches have begun to involve more activities and discussions. In a study of Taiwanese and Australian students, Aldridge and Fraser (2000) found that Taiwanese students focused more on the learning task, and the Australian students on the social interactions; although the Taiwanese students perceived their learning environment as more task oriented, they rated it more positively than the Australian students. Wu and Huang (2007) concluded that Taiwanese low-achieving ninth grade students in an interactive environment "did not receive direct support from the teacher that could constantly draw their attention to the content, [and] had fewer opportunities to listen to or engage in thoughtful discussions about concepts" (p. 747). These studies suggest that in Asian contexts it would be difficult to implement a constructivist approach in a Western sense, and that substantial teacher guidance is needed in addition to activities.

It is important to note that international studies of achievement in science such as the TIMSS and PISA consistently place Asian countries well above the international average (Leung, Yung, & Tso, 2005). Clearly, innovative educational approaches should not jeopardize such positive outcomes. Whereas Western observers have considered learning in Chinese classrooms as rote and the positive outcomes as "paradoxical" (Biggs, 1996), scholars now believe that a memorization-understanding strategy proposed by Ferrence Marton can account for the paradox (Chan & Rao, 2009). Preparation for Chinese examinations requires a high degree of practice and memorization, which is facilitated by conceptualization. However, although the results are strong in terms of subject knowledge, the various strategies used to prepare students for examinations may contribute to "learned helplessness" and keep students reliant on teachers. This is why *learning how to learn* has become an important emphasis in curriculum reforms in Hong Kong (EMB, 2000). At the same time, in the 21st century, people need to be able to collaborate and deal with novel situations. Perhaps the learning sciences can make a contribution to innovate learning approaches in Asian schools by developing new approaches to the memorization-understanding strategy that support the development of higher-order thinking and collaborative skills.

Methods

Participants
Participants were 82 students from two successive cohorts of a Form 4 (Grade 10) physics course, taught by the same teacher at an English Medium of Instruction (EMI) school in Hong Kong. The school was classified as medium academic achievement based on previous HKCEE results. Lessons were conducted in Cantonese, but all learning materials were in English, and students completed all assignments and tests in English.

Goals and Design
The study is based on the first year of a two-year physics course; topics taught in the first year included heat and temperature (3 months), mechanics (5.5 months), and waves (1.5 months). The goal of the teacher's work was to explore how to improve on her previous efforts to promote knowledge building (Scardamalia, 2002; Scardamalia & Bereiter, 2006), an approach that involves collaborative inquiry and discourse aimed at advancing collective knowledge in a community. The use of Knowledge Forum®, a web-based inquiry

environment, is an important aspect of this. Specifically, the teacher aimed to develop more collaborative discourse in both the classroom and Knowledge Forum, and to improve the integration of the use of Knowledge Forum with classroom learning.

In the first cohort (Class A, 2007 to 2008), students used Knowledge Forum to discuss their own questions about physics content (e.g., a discussion to examine why Eskimos live in igloos, which would intuitively seem cold dwellings). They also used it for discussions about two short projects, in which they collaborated in small groups: designing a solar cooker, and studying motion of their own bodies on a ride at a local amusement park. Both of these projects were heavily guided by the teacher. In the second cohort (Class B, 2008 to 2009) some modifications were made to this design: An interactive white board (IWB) was installed to facilitate easier crossing between classroom talk and work in Knowledge Forum, and the amusement park projects were replaced by projects in which groups of students designed their own experiments to investigate motion through a resistive medium. However, the teacher's workload was heavier that year, and Knowledge Forum was started three months later than in the previous year.

Data Collection and Analysis

Classroom Observations

To gain an understanding of the classroom ethos and discourse, the researcher observed double lessons conducted in the physics lab once to twice per month throughout the project; approximately 400 photographs and 20 hours of video were collected. To facilitate discussions with the teacher, several short movies (5-7 minutes each) were produced from these materials. Choices about what to emphasize in these reified the researcher's interpretation of what was happening that was relevant to knowledge building. These movies also were discussed with several other teachers and researchers working on knowledge building in South-East Asia. Interpretations were also revised based on extensive reading of the literature on teaching and learning in Confucian-heritage contexts (summarized earlier). Thus, interpretations were triangulated in several ways.

Assessments of knowledge, learning process, epistemic beliefs, and attitudes

Extensive data were collected to measure what students were learning and to explore its relationship to work on Knowledge Forum, epistemic beliefs, and attitudes towards science. As much as possible, instruments were used that have been used widely in Western contexts, and that were validated for Hong Kong students. Some additional assessments consisted of assignments designed by the teacher or researcher. Due to space limitations only results for the mechanics unit are discussed here, see Table 1 in the results section.

Force Concept Inventory (FCI): This survey remains very popular in the PER community and has been administered to thousands of students (Hake, 1998; Hestenes, Wells, & Swackhamer, 1992). Several items that related to circular motion and projectile motion (which were not part of the curriculum) were removed.

Learning reflections: At the end of the mechanics unit students were asked to write a short essays to respond to two questions: "What is your big learning about mechanics?" and "What is the most difficult question you now have about mechanics, and what would you need to know to understand it?" Most students wrote up to one page for each question. Protocols from the heat and temperature unit from Class A were used to develop three scales with acceptable inter-coder reliabilities: *Content Knowledge*, *Everyday Applications*, and *Self-Awareness*. Content Knowledge refers to students' ability to recall the main points of what they had learned about physics concepts and phenomena; at the highest level of the 1 to 4 scale students needed to reveal insight into this knowledge (e.g., point out inter-relationships between ideas). Content Knowledge is a general indication of physics knowledge, whereas the FCI provides detailed information about students' conceptual understanding. Daily Applications similarly assessed students' ability to use their knowledge of physics to explain phenomena from daily life. This ability is needed for the HKCEE, in which students are required to answer questions about a short newspaper article that involves physics knowledge. Self-awareness is a measure of students' ability to identify the strength and weaknesses of their knowledge and how they were able to learn. For simplicity of presentation, we converted the results to percentages.

In-class tasks: Two tasks were designed to assess students' understanding and explanations during the unit. A *Graphing Task* was given after the first lesson on motion graphs; students were asked to draw *s-t*, *v-t*, and *a-t* graphs relating to riding a bicycle around the school, and to state their main idea, something they wondered about, and something they wanted to raise for discussion. At the end of the mechanics unit, students used a cartoon involving a horse and cart, in which the horse argues that it is impossible to get the cart moving, and were asked to state, with reasons, whether they agreed with the horse (Explanation Task, N3).

Epistemic beliefs: It is assumed that the knowledge building can lead to more sophisticated views about knowing and knowledge. Therefore, epistemic beliefs were measured using a Chinese version of the Epistemic Belief Inventory (28 items on 7-point Likert scale, see Schraw, Bendixen, & Dunkle, 2002). The questionnaire was validated using 484 Hong Kong students taking Form 3 and Form 4 science courses. Exploratory and confirmatory factor analysis revealed three factors with acceptable reliability: *Innate Ability*, *Simple Knowledge*,

and *Quick Learning* (alphas 0.75, 0.68, and 0.66). Li (2009) suggests that Chinese learners do not hold Native Ability beliefs but the relatively clear factor structure suggests that Hong Kong science students *do* hold them. Preliminary analysis showed that there were no statistical differences between pre-test (start of the school year) and post-test (end) results; therefore, only the post-test data are reported.

Attitudes Toward Science: A 14-item questionnaire (5-point Likert scale) was used to measure attitudes towards science such as anxiety and interest at the end of the year. It was validated using 101 Form 4 science students taking science (Chronbach alpha 0.93).

Contributions to Knowledge Forum: Six indicators of contributions to Knowledge Forum were measured (see Table 1 for details). These have been used widely in previous studies involving Knowledge Forum.

Results and Discussion

Classroom ethos and discourse

The four pictures in Figure 1 are intended to illustrate the learning environment that was observed and then enhanced by introducing an IWB.
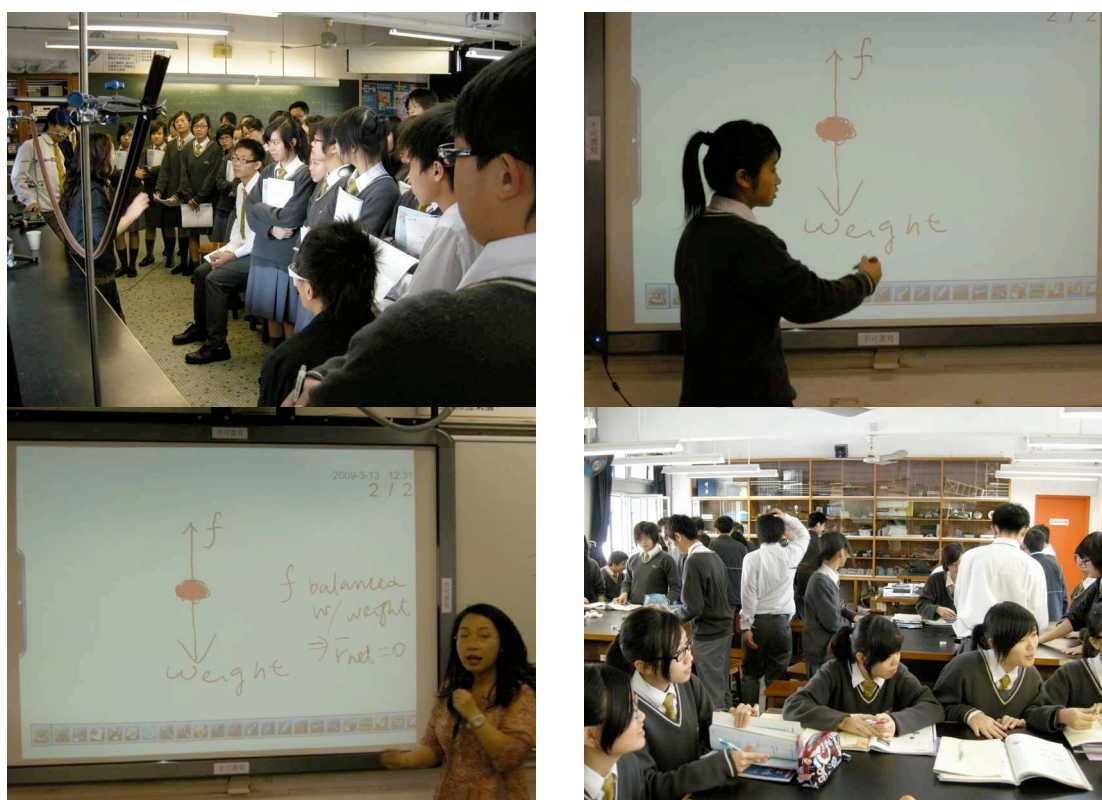

Figure 1: Classroom Environment

At the *top left*, the students gather around the teacher, who is demonstrating an experiment involving conservation of energy; the concept has already been studied, but this time there is not enough time or equipment for the students to do the experiment in small groups. Although the students are not doing the experiment themselves, the teacher's explanations and questioning lead them to consider the "critical details" of the situation (Viennot, 2003); students may demonstrate their engagement by replying to some questions in unison. The picture at the *top right* illustrates a social practice that the teacher has cultivated, in which students first explore ideas in their small groups, and then come to the front of the room to share and explain their ideas to the class. In the picture, the student is preparing her board work before explaining it to the class. Chinese learners tend to consider things privately before sharing their own thoughts publicly and avoid the possibility of "losing face" (Li, 2009), so this kind of practice is difficult to achieve. The teacher developed the practice over approximately one month in quite a structured way. First, students developed their ideas in the privacy of their groups, and two students were called to the front to present their group's ideas. Over time it became more spontaneous, and the presentations led to dialogue, in which other students questioned the presenters or helped them improve their explanations. At the *lower left*, the teacher reinforces the main points in a short and focused presentation. During a discussion driven by students' ideas there often are blind alleys and multiple

explanations; although the students mostly figure out the correct explanations, there is a danger that minor points became salient for students or that flawed explanations are remembered. Thus, the teacher reviews what has been accomplished and what is most important to remember; in this, she is using the ideas and writing contributed by students as the raw material for her own explanations. Finally, the *lower right* shows something typical of Western classrooms. There is no obvious focal point in the classroom, and many things are going on simultaneously. At such moments we typically find the teacher assisting students (e.g., getting materials for them, help to fix problems).

With this brief depiction I want to suggest that a learning environment developed in which student ideas and working to getter to develop and improve explanations were central. In this environment, students had much work to accomplish independently, but the teacher played an essential role in providing the supports needed to make their efforts worthwhile (Hmelo-Silver, Duncan, & Chinn, 2007). These developments occurred in both classes and are important to knowledge building. However, there were two problems. (1) In Class A it was difficult to connect work on Knowledge Forum with the classroom discourse; students worked on Knowledge Forum after school and the database was not accessible to them during their small-group discussions. This problem was addressed for the second cohort by installing an IWB, and making one laptop computer available during class to each small group for reviewing the Knowledge Forum database. (2) The approach required considerably more time, and made it more difficult to cover the curriculum. Perhaps fuller integration of Knowledge Forum and classroom discourse may address this problem to some extent, if some of the work to develop explanations can be moderated and completed successfully in Knowledge Forum.

Descriptive Statistics

Descriptive statistics are shown in Table 1.

Table 1: Descriptive Statistics

Measure	Class A (2007 to 2008)		Class B (2008 to 2009)	
	M	SD	M	SD
FCI pretest	32.8	18.7	29.6	12.8
FCI posttest	47.0	15.5	47.1	21.0
FCI normalized gain	0.16	0.33	0.26	0.28
Content Knowledge	55.6	18.1	42.7	16.3
Everyday Applications	61.5	14.6	59.2	19.8
Self Awareness	66.1	18.1	61.6	17.0
Graphing Task (bicycle)	53.6	19.2	36.7	11.3
Explanation (N3)	50.0	31.6	--	--
Innate Ability posttest	3.28	1.25	3.77	1.26
Simple Knowledge posttest	4.23	0.91	4.17	1.05
Quick Learning posttest	2.59	0.93	2.81	1.12
Attitude to Science posttest	4.17	0.45	3.69	0.57
Notes Created	21.5	9.33	10.2	4.88
% Notes Linked	70.9	11.7	68.0	18.3
% Notes Read	5.81	2.94	18.3	16.6
Views worked in	9.14	2.29	4.73	0.90
Revisions	4.79	4.64	5.63	8.21
Scaffold Uses	20.3	27.1	8.78	4.95

The following observations can be made: (1) The FCI results were consistent with previous research for traditional teaching. For example, Hestenes et al. (1992) studied results from 612 Arizona high school students and obtained a mean pre-test score of 27% and a posttest score of 48%. In a meta-analysis including 1113 high school students, Hake (1998) referred to normalized gains (gain divided by maximum possible gain) as small. However, Hestenes et al. also found that posttest results frequently exceeded 60% if an "active learning" approach was used (normalized gain > 0.45). Suppapittayaporn, Emarat, and Arayathanitkul (2010) also obtained a normalized gain of 0.45 for Grade 10 students in Thailand who used an approach that combined peer learning with structured inquiry. These studies suggest that although the normalized gains that we observed were consistent with traditional teaching, larger values should be possible with a research-based active learning approach like knowledge building. (2) The results for the three learning reflection scales and two in-class tasks are included mainly to pilot test these instruments. They had appropriate properties for use in future design experiments (e.g., mean, SD, and discrimination). In both classes, mean scores were highest for Self-Awareness and lowest for Content Knowledge. (3) In both classes, epistemic beliefs ranged from Innate Ability (strongest) to Quick Learning (weakest). This finding is somewhat surprising because the literature suggests that Chinese

learners do not have strong beliefs in native ability, but rather believe in effort Li, 2009). (4) Indexes of participation in Knowledge Forum in Class A were low compared to other studies (Niu & van Aalst, 2009; van Aalst, 2009), which suggests that the use of Knowledge Forum was not optimal. The improvement in the Percentage of Notes Read from 5.81% to 18.3% can be attributed to the new strategy to use laptop computers during class to access Knowledge Forum. Other differences between the cohorts are spurious due to the later start of Knowledge Forum.

Analysis of Correlations

To test for predictive relationships among the variables, the measures of contribution to Knowledge Forum were combined using exploratory (principal components) factor analysis, and path models were constructed for each cohort. For Class A, Notes Created, Percentage of Notes Read, Views Worked In, Revisions, and Scaffold Uses were factorable into a single factor, *ATK Productivity* (KMO = .771), which explained 62.8% of the variance of the five included variables. For Class B the indicators were less factorable (KMO = .618). There were two factors that explained 69.5% of the variance, the first being similar to ATK Productivity, and the second having the highest factor loading for Percentage Notes Linked. But the second factor was not clearly interpretable as some of its marker items had factor loadings exceeding 0.30 on the first factor. This result suggests that contributions to Knowledge Forum in Class B were more complex than in Class A—although less extensive. Only the ATK Productivity factor was used for the path models.

Due to the small sample sizes the path models are used only in an *exploratory* sense, and only the most promising predictive relationships are reported. These need to be considered suggestive and would need to be verified in a study of a substantially larger sample. The most interpretable results were as follows:

- *ATK Productivity* was the strongest predictor of *Content Knowledge* in Class A (weight $w = 0.54$, $p < .001$), but it did not predict the *FCI normalized gain* ($p > .10$). This suggests that writing notes with ideas relevant to the subject made a strong contribution to general content knowledge, but was insufficient for gains in detailed conceptual knowledge, such as measured by the FCI. FCI gains were only a weak predictor of content knowledge ($p < .10$), which suggests that the two measures captured different aspects of knowledge. In Class B, ATK Productivity did not predict Content Knowledge or FCI normalized gains, but this can be attributed to the lower ATK Productivity scores.
- In Class A *Content Knowledge* ($w = -0.48$, $p < .001$), and in Class B *Everyday Applications* ($w = -0.43$, $p < .01$) were strong inhibitors of *Self-Awareness*. This can be explained if high-performing students on Content Knowledge/Everyday Applications were less reflective—perhaps more sure of themselves—than low-performing students. Verbal responses from the Graphing Task support this interpretation.
- Only weak relationships between the epistemic belief measures and other variables were found. In Class A, *Quick Learning* predicted a decrease in *Attitudes towards Science* ($w = -0.35$, $p < .05$), and *Innate Ability* predicted performance on the N3 explanation task ($w = 0.33$, $p < .05$). The first result is expected because physics does not involve quick learning; the second result may again indicate that students who were confident in their knowledge and attributed this to their ability were more likely to be able to provide correct explanations. In Class B, epistemic belief measures did not predict any other measure, but the poorer result on the Graphing Task was a strong predictor of slightly less favorable Attitudes toward Science ($w = 0.49$, $p < .001$). Thus, limited success on academic tasks early in the unit may be a stronger inhibitor of attitudes towards science than epistemic beliefs.

Digging into the In-Class Tasks

The idea with the in-class tasks is that they can easily be incorporated into teaching and provide additional data points regarding students' knowledge, explanations, and problem solving as a unit unfolds. It is therefore worth looking more deeply into what they reveal about student thinking. The following informal analyses were completed only for Class A.

For the *Graphing Task*, scores from the graphs were used to divide the class into below median and above median groups. Verbal responses were then analyzed for each group, using the following categories: procedural, graph feature, conceptual question, higher-order thinking, and problem posing. For example, 'procedural' referred to procedures such as how to use motion detectors and formulas, and 'graph feature' indicated that a student had correctly described a graph feature. A question was coded higher order thinking if it sought understanding at a conceptually higher level, for example, if a student said s/he needed a clearer understanding of the relationships among the graphs or introduced a conceptual issue that had not been considered before, such as whether a vertical section of a *v-t* graph could be exactly vertical. Responses for "I would like to raise …" were coded *problem posing* if they raised a conceptual problem.

The results indicated that: (1) Above-median students wrote shorter responses (40 words on average, compared with 60), and more often used formulas or symbols. (2) Almost all students provided at least one correct description of a graph feature. (3) The below median asked many conceptual questions (15, compared

with 7 for the above median group). This result is encouraging because it suggests that below-median students were engaged with the concepts to be learned, even if they did not understand them deeply at the time. (3) Above median students made more procedural statements and problem statements. (4) Both groups asked few statements coded as higher-order thinking.

Students' responses to the *N3 Explanation Task* were divided into four categories: agreement with the horse (incorrect); disagreement without providing an analysis based on physics principles, or with an incorrect analysis; disagree with a mostly correct analysis (minor errors), and disagree with a fully correct analysis. Results showed that almost all students came to the correct conclusion (which is common sense), but relatively few used physics principles to construct their argument (14 of 41 students). Nevertheless, ten students provided a completely correct argument. Although these results are somewhat disappointing for an active learning approach—the issue that was probed is fundamental to understanding Newton's third law—there was scope for the diffusion of accurate knowledge within the class. Knowledge Forum can facilitate this diffusion.

Conclusion

The goal of this study was to explore how knowledge building could be developed in a way that is sensitive to Asian values and practices. It was argued briefly that although the influence of Confucianism has been declining in the 20th century, the major goals of education in Asia continue to be self-improvement and upward social mobility, and that the HKCEE is a difficult examination. To cope with the level of difficulty, students use an approach that combines efforts to understand with memorization and extensive practice, and teachers reserve extensive instructional time for practice for the examination (Chan & Rao, 2009; Gao, 1998). In this kind of cultural context, although students may interact with each other, it is unlikely that the teacher would implement a primarily activity-based approach—whole-class teaching and teacher guidance remain important (Wu & Huang, 2007). The four pictures in Figure 1 depicted the mix of teacher guidance and student agency achieved in the two classes of this study. The approach the teacher developed included didactic whole-class instruction, eliciting the ideas of students, student-student talk, the teacher's work to emphasize critical details, and independent work by students. It is proposed that this environment is a significant step towards an interactive learning environment suitable for Hong Kong schools.

The study used a variety of measures to study students' performance, and led to many insights into how knowledge building may be developed or studied in Asian contexts. I briefly reiterate three points.

First, although result in terns of conceptual knowledge were acceptable in the setting studied, and consistent with research on traditional physics, future work must aim for larger gains. There are good reasons to think that mean posttest scores of approximately 60% are possible (Suppapittayaporn, et al., 2010; Hake, 1998; Wells et al., 1992). As a PER-based approach, knowledge building must ehnace the extent to which students develop conceptual knowledge. The instructional apprioach was focused on conceptual knowledge, but the processes started in the classroom may require extension. It is hypothesized that further development of the approach the teacher began to implement in Class B, which involved creating a more seamless learning environment in which the use of Knowledge Foeum was integarted with classroom events, is nececsary.

Second, the study suggested how this may be accomplished. Productivity in Knowledge Forum (writing and reading notes) made a significant contribution to general physics knowledge, but not to conceptual knowledge. As the path weight for productivity in Knowledge Forum was relatively high, it may not be possible to enhance conceptual knowledge by increasing productivity alone. It is hypothesized that a direct effect from Knowledge Forum on conceptual knowledge may be possible if relational aspects of work in Knowledge Forum are increased (i.e., notes that establish linkages, synthesize progress, and identify rise-above ideas). This would require explicit attention to the development of sophisticated uses of Knowledge Forum (van Aalst, 2006).

Finally, the study showed that these Asian students did have epistemic beliefs, but that these did not interact with the variables studied, particularly contributions to Knowledge Forum. One possible explanation is that other beliefs such as filial piety masked such interactions. But it is also possible that the level of work on Knowledge Forum and other activities were not sufficient to cause changes in epistemic beliefs. Further research would be useful to shed additional light on this question.

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