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Blended learning for building student-teachers' capacity to learn and teach science-related interdisciplinary subjects

The case of Hong Kong

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Abstract

Purpose – The purpose of this paper is to report the design and evaluation of an inter-university collaborative project entitled “Blended learning for building student-teachers' capacity to learn and teach science-related interdisciplinary subjects.” The project is a response of the science education faculty of three Hong Kong tertiary institutes to the challenge of catering to the diversity of academic backgrounds among student-teachers.

Design/methodology/approach – E-learning modules have been produced covering four content domains of science. These modules are designed based on the 5E learning model and are delivered to students using the learning management system provided by Moodle. The design of the modules is iterative, based on the evaluation of three consecutive rounds of trials through student surveys, and focus group interviews with students and course lecturers.

Findings – The evaluation findings indicate positive outcomes for certain attributes such as conceptual understanding, eagerness and confidence in learning science, and metacognitive reflection on students' own learning. There are challenges to be met in relation to instructional design to cater for the diversity of student abilities, and enhance motivation in self-directed learning.

Practical implications – The project indicates the ways to develop students' basic science knowledge in a mixed-ability setting through the design of self-directed e-learning modules blended with their major courses and possible measures to address the limitations of such design.

Originality/value – The study represents a conscious effort for the science teacher education faculty of different universities to pull together to tackle a perennial teaching and learning problem.



The findings provide important insights into possible ways to blend e-learning with face-to-face learning approaches to better cater to the needs of science learners with mixed abilities to prepare them for interdisciplinary teaching.

Keywords Science teacher education, Blended learning, E-learning, Instructional design, Mixed-ability teaching

Paper type Research paper

Background of the project

The project addresses the problems that science teachers face in Hong Kong. At the primary level, science is not taught as an independent subject; it is integrated with social studies and health education to form an interdisciplinary subject, general studies. The implication for teacher education is that general studies teachers may have varied backgrounds in science. At present, many teachers are drawn from non-science streams. These teachers lack the essential science background to teach science concepts and process skills. The problem of differing levels of competence of primary teachers in science is likely to be exacerbated by the recent implementation of the new senior secondary curriculum in Hong Kong, which provides students with even greater flexibility in their choice of subjects. Students now may or may not opt for any single science subject, such as physics, chemistry, or biology, making the background of prospective student-teachers in science even more diverse than ever.

Science teacher education at the secondary level may also experience problems for two reasons. First, science teachers, regardless of the pure science disciplines they majored in at university, must teach junior secondary science to students aged 12-15; this course integrates physics, chemistry, and biology. Second, a new senior secondary subject, liberal studies (LS), was implemented in Hong Kong several years ago; this course focuses on developing secondary students' critical thinking skills through an issue-based approach applied to various contexts, including public health, energy, and the environment. LS teachers thus have the implied need to have a basic mastery of science concepts and scientific reasoning, which many non-science teachers are likely to lack.

Inadequacy of current provisions to address the learning issue

Program evaluations by both students and tutors at the Education University of Hong Kong have consistently indicated that the courses on science for student-teachers are pitched at too high a level for those with little background knowledge in science. These student-teachers often have difficulty understanding the more advanced science concepts taught in science-related courses. Apart from their lack of basic science knowledge due to their choice of non-science subjects at the senior secondary level, there are other cultural factors such as self-image that impinge on their alienation from science (Wegerif *et al.*, 2013). This inevitably influences their confidence to teach science-related topics. Research on science teachers' performance in teaching secondary science subjects outside their specialization indicates that such teachers generally have less confidence than when they are teaching their specialist subjects (e.g. Dillon *et al.*, 2000), have more misconceptions about subjects outside their specializations (e.g. Kind and Kind (2010), and are less capable of handling students' conceptual problems (e.g. Käplyä *et al.*, 2009). The inadequacy of scientific knowledge, particularly among primary and junior secondary teachers, has been a cause for concern in both Hong Kong and the USA (So *et al.*, 1998; National Research Council, 2007). Research has demonstrated that teachers' intentions to teach science through inquiry, an approach highly recommended for teaching science, and their self-efficacy (Liang and

Richardson, 2009) are determined at least partially by their perceived level of mastery of content knowledge (Luera *et al.*, 2005). Moreover, teachers' previous learning experience in science, their perceptions of the nature of science and inquiry, and their understanding of the process of learning science by inquiry may all affect their ability to teach science through inquiry (Avraamidou, 2012; Liang and Richardson, 2009; Varma *et al.*, 2009; National Research Council, 2007).

Existing practices in the Institute to address student diversity often involve the inclusion of supplementary science content pitched at a more foundational level. However, this has not solved the problem because of insufficient contact time and the wide diversity of students' understanding of science. Some students have difficulty in catching up, while others with stronger backgrounds in particular areas of science find the content not challenging enough and become demotivated. Some lecturers have resorted to face-to-face coaching and tutorials for students in need on an ad hoc basis, but these measures are usually not well structured and organized and often do not have a significant effect on students' learning. Such problems are more acute for postgraduate student-teachers, whose programs are often too short to focus on subject content knowledge in addition to pedagogy, and for part-time in-service postgraduate student-teachers, who spend only limited time on campus.

Theoretical underpinnings and paradigm shifts in learning

Blended learning approaches have become increasingly common in tertiary education around the world. These approaches often involve the use of self-directed learning materials delivered through a learning management system (LMS) to supplement face-to-face teaching. Learning management tools include blogs, quizzes, journals, online discussions, virtual lectures and activities, e-portfolios, and feedback. The advantages of blended learning are increasingly being recognized; these include the provision of new learning environments, more opportunities for learning, less dependence on teachers, the facilitation of cooperation among students, and the recognition and reinforcement of students' efforts (Gil and Garcia, 2011). Blended learning fits with the constructivist approach to learning, which recognizes the role of the learner in constructing knowledge rather than receiving knowledge passively from the teacher. This approach entails the provision of a learning environment that is conducive to self-directed learning to fit with the learner's own experience and cognitive ability (Condie and Livingston, 2007). Even for those that have studied science at senior secondary levels, they are not necessarily familiar with different areas of science or do not have experiences in interdisciplinary learning that are necessary for teaching socioscientific issues (Thomson and Tippins, 2013). Fensham (2012) points out that addressing this type of complex issues entails the application of multi-disciplinary knowledge and scientific reasoning, a process that obviously requires broader and deeper understanding of science. It is also essential that a constructivist learning environment can facilitate the development of metacognitive skills to enable learners to reflect on the efficacy of their learning processes and regulate their own learning strategies to achieve their desired learning outcomes (Thomas, 2012). In short, in such a learning environment, the learner is expected to be self-regulated, with learning becoming internally rather than externally controlled (De Kock *et al.*, 2004).

Latchem and Jung (2010) argue that blended learning helps to motivate student learning and make the purposes of learning more explicit and clear to the learner. By blending e-learning with conventional classroom learning, students could "take advantage of much of the flexibility and convenience of an online course while retaining

the benefits of the face-to-face classroom experience” (Dziuban *et al.*, 2011, p. 17). Moreover, blending the two different learning modes is highly flexible and can be tailored to the specific needs of different learning or subject contexts such that learners can take control and personalize their learning (Condie and Livingston, 2007) in an environment also oriented toward developing their self-regulation and metacognition. For science learning, different strategies can be embedded in blended learning, including virtual lectures (Gosper *et al.*, 2008), virtual lectures followed by group-based problem-solving activities in the classroom (flipped classroom), interactive simulations (e.g. University of Colorado Boulder, 2013), and technology-assisted investigation activities such as a remote-controlled laboratory (Gröber *et al.*, 2007). Thus, blended learning constitutes a paradigm shift toward more diversified goal-oriented and personalized pedagogies.

The main thrust of the project is to design a series of basic science modules to provide student-teachers with the necessary foundation for acquiring more advanced content knowledge from their major courses. These modules are designed together by three institutions, namely, the Education University of Hong Kong, the University of Hong Kong, and the Chinese University of Hong Kong for integration into existing courses in a flexible way to meet different course requirements. The pedagogical design of these modules is based on a blended learning mode that combines the advantages of e-learning and face-to-face contact. The e-learning component is delivered through Moodle (2.7), a LMS, which will be used as the major learning platform. An advantage of this kind of LMS is that it is familiar to students and contains a wide array of e-learning tools, such as quizzes, journals, blogs, and discussion forums. This learning environment allows self-pacing by students under the guidance of the course tutor. It is also intended to provide role models for student-teachers who have already obtained a science degree on the use of interactive e-learning strategies blended with traditional face-to-face teaching to extend their pedagogical repertoire in science teaching. It is hoped that this joint venture amongst the three universities will contribute to the building of the capacity of local science education faculties to design and implement creative and innovative teaching and learning strategies to address curriculum and learning issues in teacher education.

This project comprises four progressive stages of development. The first stage is the design of learning modules that can be integrated with existing teacher education courses to enhance student-teachers’ understanding of basic science. Such understanding constitutes the basis for their mastery of science-related content and pedagogical knowledge and skills. The second stage is the piloting of these modules in relevant courses. The third stage is the evaluation of the trials. The final stage is the revision of the module design for more effective learning and integration with existing courses. However, in actual implementation, these four stages are integrated to varying extents.

Stages of module development

Stage 1: design of basic science learning modules

Structure and organization of the learning modules. The design of the foundational science modules forms the basis of this teaching and learning development project. These modules cover major areas or topics of science that are fundamental to teacher education courses across the three institutions. A detailed examination of the existing courses suggests that the proposed foundation science modules can best be organized into four content domains: “Nature of science and scientific inquiry,” “Life and health sciences,” “Energy and physical phenomena,” and “Materials in the environment.” The “Nature of science and scientific inquiry” domain provides the foundation for the study of science-related methods courses such as Teaching of Critical Thinking in

General Studies, LS and Methods of Inquiry, and Science and Technology in Society while also contributing to all science-related courses. The “Life and health sciences” domain is the foundation for the Natural World and Healthy Living, Biochemistry of Health and Disease, and Teaching of Junior Secondary Science courses. The “Energy and physical phenomena” domain supports The Technology and Usage of Energy, Forces of Nature, and Teaching of Junior Secondary Science courses. The “Materials in the environment” domain is fundamental to Environmental Studies, Introduction to Environmental Science, and major methods course: LS. The division of each module into different levels of complexity allows course lecturers greater flexibility in integrating appropriate topics into their courses and allows them to build students’ knowledge foundation before introducing more advanced and applied knowledge. To capitalize on the expertise of individual team members and to enhance collaboration among the participating institutions, the project team is divided into different working groups, including the Steering Group, the LMS Development Group, and Module Development Groups under the four different domains.

The learning process and principles of instructional design. The learning process that underpins module design is based on the constructivist paradigm that recognizes learners’ active construction of meaning from educational and other life experiences. Student-teachers without formal training in basic sciences are prone to alternative conceptions arising from their own interpretations of science-related information encountered in their daily life. Thus, the recognition of these conceptions is instrumental in scaffolding conceptual change (National Research Council, 2007). To align with this paradigm, the 5E instructional model developed by the Biological Science Curriculum Study has been adopted as the framework for the design of the learning modules (Bybee *et al.*, 2006). This instructional model consists of five phases of learning. In the engagement phase, students are engaged in short activities to motivate them and elicit their prior knowledge. In the exploration phase, they are presented with activities that help to identify misconceptions and facilitate conceptual change. The explanation phase allows students to explain their understanding of the concepts and receive input from teachers to guide them toward a deeper conceptual understanding. In the elaboration phase, students are challenged to extend and apply their concepts to develop a deeper understanding through additional activities. In the final or evaluation phase, students and their teachers evaluate their own progress toward achieving the educational objectives. Research findings on science learning have consistently pointed to the instrumental role of inquiry-based approaches that encompass asking and defining questions, planning and carrying out investigations, analyzing and interpreting data, and constructing explanations in developing students’ conceptual and procedural understanding (National Research Council, 2012). Thus, inquiry activities will be used as appropriate in the exploration through the elaboration phases to facilitate learning.

Integration and articulation with existing courses. Because of the interdisciplinary nature of most of the existing courses, it is envisaged that a single module may support one or more courses and, conversely, that a single course may be supported by two or more modules/topics. Students may be assigned to visit relevant topics in a foundation module and complete the activities before the course lecturer introduces them to more advanced scientific or interdisciplinary concepts in the course. Alternatively, students may visit specific topics in a module (e.g. “Viruses and micro-organisms”) to understand or consolidate their understanding of the basic concepts that they need to draw upon in subsequent discussions on related interdisciplinary topics (e.g. the

prevention of infectious diseases in a public health course) or on the choice of pedagogy in teaching those concepts in methods courses.

Instructional design. The foundation modules/topics are designed for different degrees of blended learning, from a high degree of self-directed learning to a relatively high degree of integration with face-to-face lectures. Law *et al.* (2000) suggested a range of teaching and learning strategies into which ICT can be infused to support students' learning. These strategies include exposition, induction for seeking explanations, task-based learning that situates learning in interesting and engaging tasks, problem-based learning for identifying problems and developing knowledge for problem-solving, and social constructivist learning that encourages collaboration. Hence, our instructional design extends beyond the virtual lectures or tele-lectures commonly employed in Asian e-learning programs (Latchem and Jung, 2010) to include these various strategies. Students are guided through a series of learning activities in the LMS that are designed and presented at progressive levels of complexity. In studying the module/topic assigned by the course lecturer, students can skip certain parts of the module according to their science background and focus on those parts that are new or not so familiar to them on the condition that they satisfactorily complete the relevant assessment tasks. Students are required to complete a pre-test specific to each topic to assess their prior understanding and a post-test to allow them and their course lecturer to assess their learning after the completion of a module. The course lecturer may also assess students' performance by tracking the quality of their work as recorded by the LMS. Those who are not able to meet the learning goals will be asked to revisit the topic or to consult with the course lecturer/tutor. Students' performance in the blended learning modules may contribute to their final grade in any course in which these modules/topics are embedded at the discretion of the course lecturer.

Although a computer-based learning environment facilitates self-paced learning, its freedom of navigation and loose sequencing may not be conducive to effective learning (Greene and Land, 2000; Jacobson and Archodidou, 2000; Jonassen, 1996) or match with the learning style of individual students. To address these potential problems, discussion forums were built into the platform where students can post their queries. Moreover, the course lecturer can check their progress via the tracking mechanism available in the LMS. To help students reflect on their own learning after the completion of the module, three questions are posed to students: "What have you learned from this part/module?" "What do you think the module writer could have done to help you learn better?" and "After studying this part/module, what would you like to learn more about this topic?" This kind of reflection fits with the constructivist paradigm of learning whereby students are led to think metacognitively about their own learning and how it could be further improved. Research has shown that such metacognitive monitoring and control is important for the development of self-regulatory processes and is a predictor of achievement in an e-learning environment (Azevedo *et al.*, 2004; Greene and Azevedo, 2009). More importantly, e-learning on a self-directed basis will be blended with face-to-face contact with the course lecturer. Face-to-face contact serves various purposes, including introducing students to the e-learning environment and the associated e-learning tools, explaining the operations of online individual and group activities, following upon online activities, and providing consultation to student groups that need further conceptual clarification.

Transforming the instructional design into a learning flow using LMS. Based on the 5E instructional model, the blended learning process involves the following steps, although these steps were integrated to meet the needs of individual courses:

- Step 1: learners' self-analysis of needs based on their understanding of the topics as revealed by diagnostic tests.
- Step 2: presentation of triggers/scenarios to motivate students to investigate the underlying scientific concepts (engagement).
- Step 3: inquiry into the topics through learner-centered individual or group activities supplemented with systematic inputs such as animated PowerPoints and computer simulations and modeling (exploration).
- Step 4: development of explanations relevant to the inquiry with the support of online and face-to-face tutorials (explanation).
- Step 5: application of scientific concepts/skills to wider contexts to facilitate deeper learning (elaboration).
- Step 6: self-assessment with outcomes feeding back to the student and tutor (evaluation).
- Step 7: self-reflection to review personal learning progress (evaluation).

Stage 2: piloting the foundational science modules

The pilot testing of the foundational science modules was conducted in three rounds. In each round of trial, each participating institution selected courses in which particular modules will be tested. The course lecturers and the project team members discussed how these modules could best be integrated into the course to achieve the intended learning outcomes. The course lecturer could carefully monitor students' progress and performance in various assessment tasks as recorded by the LMS (e.g. quizzes) to evaluate their achievement. The second and third rounds of the trial involved re-trial of modules revised after the first round if the teaching timetable allowed so that the module design could be improved in an iterative manner. Before each trial round, professional development workshops were provided to the course lecturers to familiarize them with the e-learning platform, the associated e-learning tools, and the various technology-assisted tools for learning science. The course lecturers also carefully recorded the ways in which they used the modules in the trial to provide essential background information for evaluation.

A wide range of approaches were adopted by individual course lecturers in using the modules. These are summarized below:

- The module was assigned to students before teaching the course/topic for self-directed learning.
- The module was divided into parts, each of which was integrated with different topic areas of the course as basic reading materials or contextual issues for discussion.
- The module was assigned to students to complete before a lecture. Students were asked to use the following week to go through it by themselves. A quiz was then administered to the students in class a week later to test their understanding of the concepts covered by the module. The lecturer then summarized the main concepts designed to build a foundation for the students to learn subsequent topics.

- The module was integrated extensively with the course content (in the case of modules on scientific inquiry). The module, a series of inquiry activities, was uploaded to Moodle for students to work on in class. Before conducting the activities, students were required to go through specially designed textual materials to learn the concepts involved in the activities if they had not learned them before. After the students had completed the activities in groups, they were asked to upload their activity outcomes in the form of video clips to the Web for sharing and discussion with the rest of the class under the guidance of the lecturer.

Stage 3: evaluation of the trials

Upon completion of each pilot phase, the project team conducted rigorous evaluations of the effectiveness of the modules and the problems encountered. The evaluation was based on data collected through pre- and post-tests to assess students' conceptual understanding, pre- and post-surveys of students' attitudes toward science learning, focus group interviews with students and lecturers, and students' reflections after studying the modules.

Stage 4: revision of the module design

The evaluation outcomes were used to inform further revision to the modules to improve their effectiveness and integration with existing courses. The end-products in this stage are a set of blended learning module kits for use in future course implementation.

Evaluation of the project

In view of the limitation of space in this paper, only some of the evaluation findings are reported in this section. Care should be exercised in interpreting these outcomes in light of the broad range of courses in which the modules were blended with conventional learning modes. Only the major findings based on the data gathered from the third module trial round in the chemistry and physics domain are presented. Despite this, we hope that these data reflect to a certain extent the effects of the project and the issues that have implications for the further development of blended learning in science in tertiary education.

Domain: materials in the environment

In this domain, two modules were trialed in the third round: "Basic chemistry for environmental studies" and "Environmental and health impacts." A total of 119 students completed both modules. Table I shows the results of the survey administered to the students before and after they completed the two modules. The results in general suggest positive effects on students' attitudes toward science learning, with statistically significant gains in self-confidence in learning science. However, when taking the students' science background into consideration, among the four groups of students (chemistry, non-chemistry, science, and non-science), the results of the paired *t*-test reveal that respondents with a background in chemistry or any science subject showed a greater tendency to avoid learning science after completing the modules. In contrast, the non-chemistry students showed a statistically significant gain not only in their confidence in learning science but also in their eagerness to learn science. A probable conjecture is that as those students with chemistry or science backgrounds

Table I.
Students' attitudes
toward science
learning before and
after completion of
the modules in the
"materials in the
environment"
domain

Science background	No. of respondents	I am interested in science			I am eager to learn science-related knowledge			I was confident in learning science			I would avoid learning science-related contents		
		Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference
Chemistry	25	0.84	0.84	0.00	0.92	0.92	0.00	0.12	0.68	0.56	-0.84	0.04	0.88
Non-chemistry	94	0.06	0.30	0.23	0.26	0.62	0.36*	-0.66	-0.13	0.53**	-0.23	-0.11	0.13
Science ^a	53	0.58	0.74	0.15	0.62	0.89	0.26	-0.06	0.55	0.60*	-0.55	0.02	0.57**
Non-science	66	-0.06	0.15	0.21	0.21	0.52	0.30	-0.85	-0.36	0.48*	-0.21	-0.15	0.06
All	119	0.23	0.41	0.18	0.39	0.68	0.29	-0.50	0.04	0.54**	-0.36	-0.08	0.29

Notes: ^aScience students refer to students that have studied at least one science subject at the senior secondary level, which may include chemistry. * $p < 0.05$; ** $p < 0.01$

might have learned similar concepts before, they might be less motivated to study basic science. However, further study is needed to substantiate this hypothesis.

Students' changes in conceptual understanding with respect to each of the two modules were gauged through specially designed pre- and post-tests. There were variations in the effects of the two modules. For the module "Basic chemistry for environmental science," there was a statistically significant increase in students' scores after they studied the module, regardless of their science background (Table II). However, for the module "Environmental and health impacts," there was a significant decrease in students' performance across all groups (Table III). This anomalous result might be attributable to the difference in assessment items between the pre- and post-test for the module. In the post-test of both modules, new items were added to those in the pre-test. However, for the module "Environmental and health aspects," the MC items were mostly replaced with written-response items. We hypothesize that the students were reluctant or had little motivation to answer this type of item because they were used to the multiple-choice type or because these items were too difficult for them.

Students provided insightful responses to the three questions to elicit self-reflection after completing each module. Most were able to cite specific concepts they had learned from the modules, such as various types of pollutants and their effects, the phenomenon of eutrophication and algal bloom, biological oxygen demand, and PM10. Many students wanted to learn more about the solutions to the pollution problems, and some wanted to gain deeper knowledge on the topics. The respondents suggested a wide range of methods to improve their learning, including more visual content, extra information, explanations of vocabulary, more readings, and more interactive activities. Only two students said they preferred face-to-face lessons to e-learning.

Table II.

Pre-test and post-test scores on students' conceptual understanding of the module "basic chemistry for environmental studies" by students' science background

Science background	No. of respondents	Pre-test	Post-test	Difference
<i>Module 1 – basic chemistry for environmental studies</i>				
Chemistry	12	42.16	58.33	16.18*
Non-chemistry	53	44.73	54.72	9.99**
Science	28	46.01	57.86	11.85**
Non-Science	37	42.93	53.51	10.59*
All	65	44.25	55.38	11.13**

Notes: * $p < 0.05$; ** $p < 0.01$

Table III.

Pre-test and post-test scores on students' conceptual understanding of the module "environmental and health" by students' science background

Science background	No. of respondents	Pre-test	Post-test	Difference
<i>Module 2 – environmental and health impacts</i>				
Chemistry	12	61.86	40.47	-21.39**
Non-chemistry	47	60.73	48.94	-11.78**
Science	27	61.61	46.56	-15.05**
Non-science	32	60.41	47.78	-12.63**
All	59	60.96	47.22	-13.74**

Notes: ** $p < 0.01$

Domain: energy and physical phenomena

In this domain, five modules were trialed in the third round, including “Transfer of thermal energy,” “Force,” “Machine,” “Electricity,” and “Introduction to waves.” A total of 138 students completed these modules. The overall results of the pre- and post-surveys are shown in Table IV with a breakdown by students’ science backgrounds. The results in general suggest positive effects on students’ attitudes toward learning science. Considering the modules as a whole, there was improvement in students’ attitudes for all items, with statistically significant gains in eagerness to learn science. The gain in confidence in learning science was statistically significant for non-physics students and for the whole group. Non-physics students gained greater confidence than the other students, probably because they lacked basic knowledge about physics but had attained a level of scientific understanding from other subjects that enabled them to benefit more from the modules than the non-science students that had not taken any senior secondary science subjects.

As fewer than 20 students participated in the modules trialed in this round (except for the module “Introduction to waves”), a paired *t*-test was only applied to this module to compare the students’ level of conceptual understanding before and after studying the module. Statistically significant gains were obtained for the “non-physics” and “science” students, implying that the module was more effective for students who lacked a physics background but had some background in science subjects outside physics (Table V).

In their self-reflection on learning the modules, students cited a variety of topics and concepts that they had learned from the modules, with detailed examples provided by some respondents, such as “how to catch a fish underwater” for the “waves” module. As to the content that students wanted to learn more about, students’ responses fell into two categories: more detailed theories and principles and more applications of theories. Again, the students made a variety of suggestions on how to improve their learning of the module content. These include more examples to illustrate the concepts, more learning materials in the form of animations and videos, deeper knowledge, more questions raised for thought with hints provided, and more support from tutors.

Lecturers’ feedback on the trial. Several focus groups were arranged with the lecturers who participated in the trial to gauge their feedback. Most of them used the modules as self-directed learning materials in addition to their regular course materials. They normally assigned a particular module or part of a module to their students either before or in the middle of the course. Judging from the pre-/post-test comparison, they thought the module materials were useful, but much depends on whether the students went through the materials seriously or merely to pass the tests. It seems that students were better motivated when they completed quizzes in class than when allowed to work on them in their own time. Students’ participation can be guaranteed only if the module is made compulsory by allocating participation marks upon satisfactory completion. The lecturers also noted that students participated more enthusiastically if the content of the module was included in the end-of-term examination.

The lecturers made the following specific suggestions after completing the first trial:

- it is more useful to emphasize the objectives of a module (e.g. self-directed learning) at the start of using the module;
- it is better to provide students with a summary when they complete a module;
- a problem-based approach could be adopted in designing the modules in which students are required to answer questions to facilitate more active learning;

Science background	No. of respondents	I am interested in science			I am eager to learn science-related knowledge			I was confident in learning science			I would avoid learning science-related contents		
		Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference
Physics	19	1.00	1.21	0.21	1.00	1.42	0.42	0.68	0.89	0.21	-0.47	-0.37	0.11
Non-physics	27	0.93	1.07	0.15	1.00	1.22	0.22	0.33	0.70	0.37*	-1.00	-0.63	0.37
Science ^a	32	1.25	1.31	0.06	1.13	1.44	0.31	0.63	0.88	0.25	-0.75	-0.75	0.00
Non-science	14	0.29	0.71	0.43	0.71	1.00	0.29	0.14	0.57	0.43	-0.86	0.00	0.86
All	46	0.96	1.13	0.17	1.00	1.30	0.30*	0.48	0.78	0.30*	-0.78	-0.52	0.26

Notes: ^aScience students refer to students that have studied at least one science subject at the senior secondary level, which may include physics.
* $p < 0.05$

Table IV.
Students' attitudes toward science learning before and after studying the modules in the "energy and physical phenomena" domain

- each module could be designed in such a way that component parts can be used separately, thereby increasing the flexibility in blending the module materials with the course content;
- students' performance on the post-test could be counted toward the overall grade of the course or the e-module content could be assessed in the end-of-course examination;
- the approach used by the e-module should preferably be consistent with that employed by the course in which the e-module is used;
- additional modules could be designed to introduce other basic concepts such as radiation, bonding structure, molecular interactions, and redox reactions;
- an e-learning week could be incorporated into the course to allow time for students to complete the self-directed learning activities in the relevant modules;
- in-class quizzes could be used to monitor students' progress and check their misconceptions after the completion of a module; and
- students should be allowed to skip certain parts of a module if they are able to gain a certain score on the pre-test.

Conclusion and implications

As judged from the evidence reported herein, we consider the outcomes to be positive and encouraging. The objectives have been achieved to a certain degree with respect to the successful development of foundational science e-learning modules to improve students' basic science knowledge and increase their confidence in learning science, particularly for those without strong science backgrounds. Students' development of metacognitive skills was demonstrated by their reflections on their own learning in terms of the knowledge gained, further knowledge they wish to gain, and suggestions for further improvement. Students were generally receptive to this kind of self-directed e-learning approach, which was blended to varying degrees with more conventional approaches, although a small proportion of students preferred conventional modes of learning. In designing and trialing e-learning materials, we experienced the capacity-building process most needed to address our concern: developing non-science students' foundation in science as a prerequisite for learning more advanced science concepts in their undergraduate programs. We also recognized the synergy generated by drawing together the expertise of the three partner institutes in creating a variety of modules and suitable Moodle tools that could be applied to a wide range of courses in a flexible way.

Table V.

Pre-test and post-test scores on students' conceptual understanding of the module "introduction to wave" by students' science background

Science background	No. of respondents	Pre	Post	Difference
<i>Module 5-introduction to wave</i>				
Physics	19	89.50	98.70	9.21
Non-physics	15	76.70	98.30	21.67*
Science	31	83.90	98.40	14.52**
Non-Science	3	83.30	100.00	16.67
All	34	83.80	98.50	14.71**
Notes: * $p < 0.05$; ** $p < 0.01$				

However, as revealed in the evaluations of both students and lecturers, there remain a number of challenges to be met to fully achieve our objectives. These challenges are not solely technical ones in terms of transforming teaching content into digital forms delivered through the LMS; they also involve applying sound pedagogical designs underpinned by evidence-based learning theories to facilitate students' construction of foundational science knowledge in a progressive and self-directed way. Hungwe and Dagada (2013) have argued that blended learning will not be successful if the lecturers involved fail to integrate "technological content knowledge" with "pedagogical knowledge" (p. 1). Another important issue to address is the motivation of students to learn science content in a self-directed way. Students' recognition of their own difficulties in learning undergraduate science does not necessarily lead to increased motivation to engage in the self-directed learning of more basic science. Our experience from the trials shows that students' motivation in engaging in self-directed learning could be enhanced by pegging it to the formal assessment of the course with which the module is blended. Both the lecturers and the students suggested measures for the more effective blending of the self-directed and face-to-face learning approaches such that more effective learning could take place by lowering the cognitive barrier for students to overcome. This echoes the findings of Condie and Livingston (2007) that the effect of blended learning on students' achievement could be increased if lecturers actively engage students in the learning process.

Apart from an increased degree of blending of self-directed e-learning and face-to-face lectures, the effectiveness of student learning can be improved by pitching the module content at a level of complexity appropriate to different target groups, identifying and supporting students in need, using a broader range of e-learning tools to cater to diverse abilities and learning styles, making learning activities more interactive and interesting, incorporating more inquiry activities to enhance students' understanding of concepts and their capacity for scientific thinking, encouraging students to reflect on their learning and learning difficulties, strengthening the provision of feedback and support to students in need, and enhancing the integration of the e-learning modules into the courses. The last point could possibly be addressed by setting aside class time for e-learning, holding quizzes in class to assess self-directed learning, and having the course lecturer provide a greater degree of facilitation to guide students through concepts that are difficult to master.

In summary, this project is challenging in that it applies blended learning approaches to solve a perennial teaching and learning problem facing both student-teachers and teacher educators arising from the unique school curriculum context in Hong Kong. The success of the project hinges on whether student-teachers can be motivated to learn basic science content in addition to the content covered by their major courses and whether more effective blended learning approaches can be designed to boost students' confidence in learning science, a subject which most of them had opted out of in their senior secondary school years. It is thus important to develop more creative and innovative learning approaches to exploit the possible resources available to address the learning problem, which is difficult to resolve solely by conventional means.

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