

Employing STEM Curriculum in an ESL Classroom: A Chinese Case Study

Gregory R. MacKinnon

Acadia University, Nova Scotia, Canada

Corresponding Author: gregory.mackinnon@acadiau.ca

Kate Greene

Edward Rawn

John Cressey

William He

Shanghai Pacican International Education, Shanghai, China

Abstract

Mixed methods action research was undertaken in a grade 6 classroom in Shanghai, China to identify the challenges of implementing science, technology, engineering and mathematics (STEM) curriculum in an English Second Language (ESL) classroom. The research has shown that while students are well-motivated to learn through a child-centred problem-based approach, the schooling context has measurable deterrents linked directly to an assessment driven system. It was further determined that the language barrier sometimes mitigated the use of higher-order terminology to promote critical thinking as defined by Bloom's taxonomy.

Introduction

STEM education has enjoyed an exponential proliferation in Western education (Chiu, Price, & Ovrahim, 2015) and as such, has garnered much attention in countries such as China (Ding, 2009; Ritz & Fan, 2015). In an effort to succeed in a highly competitive setting, many private institutions seek to offer the most current and relevant curriculum to its elementary and secondary school-age students. The potential of integrated curricula to improve student's conceptual retention and scholastic performance has been demonstrated. Consider for instance a 30-study meta-analysis (Hartzler, 2000) that concluded that students' learning through integrated curricula consistently outperformed students in traditional programs as measured on standardized tests. The same study found that integrated curricula were particularly advantageous for teaching science/mathematics and assisting students with below average achievement levels.

The science, technology, engineering, mathematics (hereafter STEM) education movement arguably has evolved from the Science Technology Society's (STS) integrated curriculum initiative of the 1990s (McFadden, 1991; Solomon, 1993) and the notion that technology education should be more a problem solving venture than the narrower vocational training tradition that emanated from the industrial revolution. The STS movement also emphasized real-world problems with societal implications and considerations. This ideological development happened in parallel with the important work of the International Technology Education Association who promoted technological literacy for all (ITEA, 2006; 2007). This pivotal organization has more recently expanded its scope to include Engineering education (ITEEA, 2015).

Given the inherent real-world connections of many integrated curricula, it has become clear to curriculum developers that they can capitalize on established benefits of constructivist (Brooks & Brooks, 1993), situated cognition (Brown, Collins, & Duguid, 1989) and student-centred learning (Bruning, Schraw, Norby & Ronning, 2004). In China, this is particular relevant due to the recent outcry of industry representatives, that students, while

very intelligent and successful in national testing, often can neither think critically nor solve real problems. These later skills are prerequisite skills for China's expanding industrial sector (Rein, 2010a, 2010b; Weihua, 2014; Anderson, 2016). As further noted by Wang, Moore, Roehrig, and Park, (2011), "The problems that we face in our ever-changing, increasingly global society are multidisciplinary, and many require the integration of multiple STEM concepts to solve them...In many cases, people need skills that cut across disciplines...STEM integration offers students one of the best opportunities to experience learning in a real world situation, rather than to learn bits and pieces and have to assimilate them at a later time" (p.13). Such problem-based learning approaches in a STEM program have already proven fruitful in the Chinese context (Lou, Shih, Diez & Tseng, 2011). Nonetheless, those in the fields of science and technology education offer a caution that the way we integrate curriculum can compromise the integrity of individual subjects and furthermore, that curriculum change is both difficult and country (context) dependent (Sanders, 2009; Williams, 2011; Yager, 2015).

Curriculum experts (Lederman & Niess, 1997) have been careful to distinguish two popular approaches to STEM integration, namely "multidisciplinary" where the identities of the individual integrated subjects are obvious, and "interdisciplinary" integration where the context of the learning blends subjects such that boundaries are blurred. These distinctions, elsewhere in the literature have been coined "silo" and "embedded" approaches (Roberts & Cantu, 2011). The consensus among educators (Morrison, 2006; Clark & Ernst, 2006) is that the integration should afford opportunities for students to focus not just on content knowledge, but also engaging inquiry through the problem solving process.

This paper focuses on the challenges faced when an academically high achieving Chinese middle school attempted to implement an integrated science, technology, engineering and mathematics (STEM) curriculum in their English language program.

Context of the Case Study

The action research case study (Schmuck, 2006) described herein, was undertaken at a primary to grade 7 private school in Shanghai, China. The students in this school take all subjects in Chinese as they prepare for regional high-stakes examinations and then English, both grammatical and conversational as additional subjects. The STEM curriculum intervention was undertaken with a grade 6 class of 19 students. These students take a STEM class once per week for one hour. Their STEM teacher was a female native English speaker from North America who in another course taught them conversational English. Given the nature of a paid education (private school) and the "one-child" government directive, the parents had high expectations that students become fluent speakers of English while excelling on their examinations in Chinese subjects. The STEM course was not evaluated by examination through the government but instead had a peripheral status.

While there remains much discussion around the nature of STEM pedagogy (Ritz & Fan, 2015) and the term "technology education" itself (Jones, Bunting & de Vries, 2013), it is important to disclose that the author is a proponent of integrated interdisciplinary curricula. Furthermore, the following definitions clarify the interplay of those subjects in the curriculum design.

- Science as a "way of knowing" that seeks to understand the world around us
- Technology as a "way of adapting" that necessarily considers societal impacts
- Engineering as a "way of formulating devices" to respond to real problems
- Mathematics as a "way to express an understanding/analysis of the world and authentic problems through numbers"

The Nature of the Intervention

The government-mandated Chinese curriculum necessarily has supplemental textbooks that support instruction in science and mathematics at the 6th grade level. In both instances, the written curriculum covers two textbooks in each subject. For each matching chapter, in each subject, the curriculum topics were translated into English (see Table 1). From a position of design, multiple activities were constructed around the science/mathematics topics by chapter with principles of engineering and technology incorporated as per the broadly expressed definitions above. Because students progressed through the chapters of their science and mathematics textbooks in sequence and the intent was to build upon their core course knowledge, it seemed reasonable to design activities that might apply, in an integrated fashion, the topics they were currently studying (see Table 1). It is important to note that not all activities contained all topics in the chapters and the relative emphasis of the engineering and technology components varied. Aspects of engineering included building models of catapults, telephones, bridges, human body systems, furniture, insulation, and wheel chair ramps. Technologies included such things as computer probes, CAD-like design programs, animation software, and a range of interactive simulations and spreadsheets. The curriculum design aligned with the approach of Sanders (2009) when he suggested that "Our notion of integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). Further, the format adopted his notion that activities should "provide a context and framework for organizing abstract understandings of science and mathematics and encourage students to actively construct contextualized knowledge of science and mathematics, thereby promoting recall and learning transfer" (p. 23).

As the content and process knowledge of earlier chapters accumulated, the activities could draw on an increasing reservoir of student content and process background. In some cases, aspects of entrepreneurial education were also incorporated. Representative samples of activity topics included furniture construction, building bridges, the catapult, exploring heart rate and space travel, controlling invasive species, locomotion, insulators and warm dwellings, and reproduction/population studies). In all cases the curriculum activities were nested in investigations that were context-rich thereby attempting to avoid the so-called "potpourri" effect where teachers incorporate all subject areas but have no central activity aim (Jacobs, 1989; Roberts & Cantu, 2011).

Table 1 : Mapping out aligned topics in science and mathematics

Grade 6 Mathematics Topics – Book 1	Grade 6 Science Topics – Book 1
Chapter 1	Chapter 1
Division of whole numbers to yield whole numbers	Nature of Science
Positive & Negative Integers	Discovery & Invention
Which #s can be divided by 2 & 5?	Safety
Factors of numbers (composite & prime #s	Measurement: length, temperature, mass, volume, time
Greatest Common Factor	Measurement: pulse, heart beat
Least Common Multiple	Combining chemicals + observation
	Observation & magnets
	Prediction, guesses & hypothesis

Research Methodology

The overarching research question for the study was “What are the factors that influenced the successful implementation of the STEM curriculum as perceived by students and educational stakeholders including the teacher?” While a survey of students’ reaction to the curriculum was important, it primarily served to identify key factors to be probed in interviews with all stakeholders. The semester end test served as an artefact to assist in triangulating the findings. Coupled with classroom observations, this overall methodology provided a cursory glimpse of the pilot implementation.

Survey

An electronic survey of 17 questions was administered to 19 grade 6 students (48:52% female:male) with a 100% response rate. The students’ teacher proofed the question format and language level in order to remove ambiguity. In addition, the teacher was present during the survey to clarify questions students may have had, given especially that the students’ first language was not English. The issue of random or careless responder (i.e., responding without regard to item content; Beach 1989) and acquiescence response bias (e.g. favoring one side of the Likert Scale) was mitigated by (a) addition of a bogus question (Meade & Craig, 2011) and (b) addition of two reverse-keyed questions (Kam & Meyer, 2015). Questions were posed using a Likert format and focused on four primary areas namely: 1) the nature of learning in the STEM classroom; 2) confidence in using computers; 3) confidence in learning in English language; and 4) the relevance of STEM in their study context. All 19 surveys remained in the sample as no responder bias or careless responder evidence was evident.

The survey was designed to inform questions to pose to stake holders; the small sample and the use of non-continuous Likert scales precluded statistical analysis. It is presumed that there is limited generalizability beyond this specific action research context; it is left to the reader to draw justifiable parallels to their own settings.

Interviews

On site in Shanghai, China, a random sample of five students in the grade 6 class were independently asked three questions about their experiences in the STEM classroom. How would you describe your experience in the STEM classroom? (positive or negative and why?) How does the content of the class compare to your other courses? How does the teaching compare to your other courses?

In addition, the following key stakeholders were asked to identify the challenges to implementing a STEM curriculum in their school context: the STEM teacher, the department head, the curriculum lead for conversational English education, the school principal and a school administrator of overall programs and facilities. The principal and administrator responded in an interview format while the others responded in writing.

Semester-end Test

The students were asked to complete a written test of questions A through H which concerned not only specific activities they engaged in (e.g. population, heart rate, locomotion), but also foundational mathematics and applied questions related to invasive species. The results are later discussed within the context of other empirical feedback.

Results

The cumulative feedback was coded for emergent trends in an iterative axial process (Strauss & Corbin, 1990) following the collection of each independent source of information.

Context

While the sample is limited to a particular classroom by design, generalizability may be extended to similar contexts; this is inherent to classroom action research. Beaulieu, (2013) captures the research intent in the following:

“Unlike other forms of interpretive research, action research is about seeking perspectives that are defined by the stakeholders, not by principal researchers, and it can involve exposing truths that are not guided by the myths of objectivity. For action researchers, seeking a singular truth or perspective is not necessarily a desirable goal. Instead, capturing the various stakeholder’s perspectives can expose a broader view of the conditions that exist in a setting and offers opportunities for developing strategies that accommodate those different views.” (p. 30)

Thematic Analysis

Student perspectives. The survey and interview data were particularly useful in defining the context of the classroom experience for the students especially in categories of student readiness and relevance of the curriculum.

Given that a portion of the STEM curriculum involved computer use, it seemed important to investigate that interaction. When posed the question of access to computers at home, 85.7% (hereafter n=19) said they regularly used a computer in the home. While 71.4% indicated they were confident using word processing and (in a separate question) Internet search engines, fewer (66.7%) were comfortable using simulations online. Similarly, 66.7% used computers to support their English learning. Overall 81% of students said they used computers for learning in their STEM classes. These were important foundations to establish as we sought to ground our findings in a developing contextual understanding. In any technology intervention study, it is important to understand the “baseline” predisposition to technology so as to appropriately judge the validity of the research findings. For instance, if students neither have access to computers or any confidence in using standard software applications, any use of new technology-enhanced pedagogy will predictably lead to confusion and student dissatisfaction; this is a skewed result in that the approach may well be productive but the baseline is negative. In this study it was found that students were quite comfortable with computer use for certain applications. However, because a portion of the STEM experiences were predicated on use of simulations, more work will have to be undertaken by the teacher to develop student confidence in this area.

Students in the survey and the interviews were positive in most aspects of implementing the STEM curriculum. The topics investigated in the STEM activities were of interest to 71.4% of the sample. Interestingly the active nature of these investigations was most appealing with 85.7% of the students liking the “way” the teacher taught these topics. In interviews it was clear that, because this was an additional course for students and, it was outside the normal curriculum, students were skeptical of the value especially as this schooling was nested in a “test -oriented” assessment scheme. The STEM activities by nature integrated science and mathematics in a problem-based approach. Students in surveys suggested they enjoyed learning science this way (76.2%) however, when asked about mathematics, only 61.9% enjoyed learning fundamental mathematics concepts through STEM activities. Given the students’ preoccupation with passing examinations (an attitude emerging from interviews) it became obvious that they looked for the most efficient

way to learn subjects quickly. In interviews students revealed that their teachers also followed a didactic model, which, predictably opposes the notions of constructivist (Brooks & Brooks, 1993) STEM activities. So while overall 61.9% of students indicated they liked to learn in this manner, 19.0% said the STEM course was interesting but they had too much other course work (fully evaluated) to complete, to take the STEM course seriously.

We suspected from our student interviews that the challenge of the STEM course was also related to the fact that English was a second language. In the sample, 57.1% said they were confident speaking English while 52.4 % said they were confident learning STEM topics in English. It was evident in the term-end test that relational phrases (e.g. compare, contrast, differences, similarities etc.) frequently used in mathematics and science were sometimes problematic for the student such that they didn't know what was being asked of them.

Students clearly enjoyed the change in pedagogy and the active role they personally took in solving situated problems. Even though there were no formal STEM examinations, students saw value in the STEM course. Students were happy (80.9%) that their school offered such a program and the same number saw that as such, their school had an advantage over the teaching and learning in other schools. Lastly, over 75% said that the STEM course should continue.

In the term-end test, students had no difficulty with the mathematics especially when they recognized the function or operations that had to be undertaken. Likewise, recall questions around science terminology were readily recognized. When the teacher moved to science and mathematics questions that involved more comprehension and analysis (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) students experienced misunderstandings about wording such as prediction or relationship and notions of multivariable synergies. In some ways the language precluded them from going beyond concrete operational (Piaget, 1954) problems.

Identifying Challenges: Educational Stake holders

The written and interview feedback from a range of stakeholders has been coded (Huberman & Miles, 2002) and discussed below in categories. Specifically, the following educational leaders for the school were asked for reflection on the challenges of implementing a new STEM program: the STEM teacher, the department head, the curriculum lead for conversational English education, the school principal and a school administrator of overall programs and facilities.

Leadership and mentorship. In a new program, the teacher immediately and necessarily becomes the STEM leader. This is particularly difficult if the teacher is new and has seen their primary role to be an ESL teacher. A better model would involve an on-site mentor that could take an active leadership role in overseeing implementation of STEM standards across all subjects meanwhile coordinating resources both human and material for the teacher to access.

As shared by the lead teacher:

"I believe one of the first and foremost challenges for implementing an applied English STEM program at our school is the lack of a present mentor of STEM at the school. Teachers are always extremely reticent to turn to avenues of support outside their school for a myriad of reasons. And, to be sure, the Chinese and foreign teachers already have a symphony of leaders they have to coordinate with on a day-to-day basis. However, when it comes to STEM, the teacher is mostly left to his/her own devices."

In conversations with the lead teacher, it became apparent that there was little interaction with the Chinese Mathematics and Science teachers. Given the language barrier, cross-curricular discussions and/or support were not easily undertaken. This was a serious impediment to maximizing the impact of problematizing standard curriculum under the STEM banner. In other words, one would hope that students would be motivated to retain standard curriculum concepts through practicing concepts and processes in STEM activities. This would no doubt be enhanced by coordination between all teachers.

Resources and collaboration. When a new curriculum is offered in a school it requires both human and physical resources. In the Chinese context even the simplest of materials were not readily available to the teacher. Doing so called "kitchen science" was not easily accomplished so this had the effect of distancing the activity from what children could actually try at home. This thereby mitigated some of the motivational value of doing problem-based learning.

Recognizing that the strength of the STEM curriculum might come out of collaboration with other teachers, the lead teacher attempted to make connections with other teachers in the school. The challenge of communicating with Chinese-speaking teachers, the newness of the curriculum, and the hard fastness of traditional teaching methods, precluded useful interactions for the lead teacher. She felt that with time this could change but that other teachers had to "buy -in" to the rationale for offering STEM curriculum and its potential to enhance understanding in standard core courses.

Time for STEM. While, ideally, a STEM curriculum could be promoted across subject areas so that the entire school situates learning in STEM outcomes, it is not likely in Chinese schools. This is primarily because the status of STEM is not yet such that the government assessment schemes include it. As per many worldwide curriculum initiatives, it is an arduous process to "enculture" a school with new standards and furthermore professionally develop the teachers for progressive pedagogies (Williams, 2011).

In this pilot study the school administration allowed for a single STEM class per week to be offered by the English Second Language (hereafter ESL) teacher. In interviews both the lead teacher and department head see this as far too little, especially considering the language barriers. The terminology that accompanies interactive STEM lessons requires some repetition if there is to be any realistic retention of understanding in students over a whole week. The teacher, in particular, found that she had to compress and modify activities in order to offer a meaningful experience for students. The single class per week model had other direct drawbacks as shared by the teacher here:

"The first obstacle is my limited time- I have about 40 minutes, once a week, to teach the topic. Even if I extend for two classes, I generally feel that I am not exploring the issue with the class in as much detail as I could be."

"Another obstacle would be the sort of stand-alone nature of the current STEM program. We have class once a week, and that's it. The topics we discuss don't necessarily appear in their other classes, with the end result that they learn something and are able, I suspect, to promptly forget about it. I want to make our STEM activities as beneficial and productive as possible, which means that I need to factor in this situation when asking myself what they should be getting from each class."

The Problem-based process: Recognizing the value. There is a need for more student-centred learning to develop critical thinking skills to advance the economy of China (Rein, 2010 a,b). Chinese children often only learn through passive teaching methods where they are simply recipients of knowledge having little involvement in personally or socially

constructing understandings. Furthermore, this sample of students suggested that it was unusual to talk about how they learned; the emphasis instead was always on what they remembered. This was corroborated by curriculum leaders who said there was little time taken in Chinese classrooms for metacognitive exercises where students might hone their problem solving skills. This is clearly an issue when one considers that a popular definition of science is a way of knowing (Moore, 1999), which gives equal weighting to the knowledge of the world around us and the process of “finding out”. Feedback suggested that, despite active learning approaches invoked by the teacher, it was a culturally-engrained challenge to get children to guess or hypothesize when they themselves didn’t already know the answer. Given the history of Chinese education, it wasn’t surprising that the parents of students also had trouble understanding the relative worth of child-centred learning that didn’t necessarily get evaluated in national testing. The notion was lost on parents and students that tapping into students’ knowledge building through situated and active learning could improve conceptual retention. This is not a new finding. Venville, Wallace, Rennie and Malone (2002) concluded that mitigating factors to curriculum change included “assessment and parental pressure for traditional standards and subject-based qualifications” (p. 54).

Said one educator:

“They (foreign teachers) assume that students can recognize they are learning when they are experimenting or having fun, and in China, this can be an erroneous assumption... to get students to reflect upon their learning afterwards and recognize their activeness as good learning is an incredibly difficult task, sometimes requiring breaking a deeply-rooted cultural stereotype about the role of the student in his/her own learning...to get students to maximize their learning, and therefore their investment in problem-based strategies, requires a re-molding of many Chinese students' concepts of what is valuable instruction.”

The reality of the assessment-based system. The relative importance of STEM in the scheme of the Chinese system may be diminished by a preoccupation with assessment. The nuances of this tension are captured below in the comments of the department head.

“Finally, students' schedules in middle school and high school in China are packed. As students approach the zhongkao (Senior High School Entrance Exam) and gaokao (National Higher Education Entrance Exam), a process of "extracurricular" triage occurs, and STEM is quick to be cut by both parents and students because it's not directly tested on those important tests. Even at the New Qing Hua school (where STEM is being piloted), I have seen the grade 6 students barred from participating in Christmas activities because powers that be feel they need to spend more time preparing for tests. As students approach zhongkao I am afraid the administrators' and even the students' own interests may decrease. I am not sure how to solve this, but I do think making STEM an elective and exclusive and even quite difficult as it progresses is really an important part of that.”

In an interview, the principal of the school corroborated this context. She said the examinations were really important for the student, the teachers (and their reputations) and the school (its performance rating). When pressed to elaborate, she agreed that the STEM curriculum was an innovative addition to the school’s offerings but that the current assessment system did not value STEM outcomes so parents were not yet convinced of its value. Despite this reality, the principal was committed to promoting STEM because she had observed the motivation it rendered to the grade 6 pilot class.

Math skills valued higher than science; Blending appropriately. Because numeracy and literacy are valued highly in country standards, the relative amount of time spent on other subjects can be small. This is true in the case of science which gets much less attention in the curriculum than mathematics. When teaching STEM classes that draw on the competency of students in these areas, it poses challenges as relayed by the teacher below.

“The second obstacle would be my lack of familiarity with my students' abilities in math and science- I am frequently surprised by how much- or how little- prior knowledge they have of the topic. I have to be quite flexible when teaching- things usually have to be adapted on the spot. I have noticed that their science skills tend to get less attention than mathematics in their education.”

While a veteran teacher may be malleable in this regard, new teachers (as in this case) tend to be less confident to move away from the standard curriculum. The curriculum leader and principal both indicated that mathematics skills in students would normally be much higher given the frequent emphasis and testing in the system albeit a rote learning approach.

Conclusions

As aptly stated by Williams (2011) “Support for a STEM approach to curriculum design must proceed with the understanding that school curriculum structures are very resistant to change” (p. 27). In the unique setting described here, there are a plethora of constraints, which mitigate progress.

The Chinese government, like many others worldwide, is emphasizing numeracy and literacy in the school curriculum. This trend is arguably diluting studies of science, social studies, physical education, the arts, engineering and technology across many curriculum jurisdictions (Walker, 2014). In many systems, assessment drives not just the “nature” of the curriculum (content) but also the way it is delivered. In our own study, students were quick to note that didactic pedagogies were much more efficient for getting the “testable” content to them than the more motivational situated learning contexts. In addition, a quick survey of the “way” students are tested shows a clear weighting towards recall rather than process skills or higher order thinking.

Because a tenant of quality education is matching active teaching and learning approaches with a system of authentic assessment that values process, it seems that STEM pedagogies may have a steep hill to climb in overcoming the embedded testing phenomena we see in so many settings. This of course is closely related to the expectations that parents have of the system. Regardless of what the system involves, parents want their children to be successful. If through lack of attention/emphasis STEM education is downplayed and seems like an esoteric activity, parents will opt for “studying that counts”. This is not lost on the students either; the teacher then must constantly sell the virtues of STEM despite the system’s predisposition.

Coupled with this challenge is the well-established hurdle of providing appropriate professional development to teachers to offer a STEM program, much less convincing them that constructivist approaches actually have impact (Roberts & Cantu, 2012). When teachers are compelled to “teach to the test”, regardless of what they know about student-centred active learning, they are likely to conform. This is particularly detrimental when new teachers to the system bring energy and innovation, but realise the system constrains them greatly (Mackinnon, 2010) so they defer to traditional “accepted” norms in the system.

The pedagogical development of STEM teachers, in this setting, is further complicated by the fact that English is not the students' first language. Imagine teaching a STEM class where you want students to predict, compare, contrast or perhaps synthesize information when they don't know what these words mean. Inherently, authentic classroom activities will invoke higher order skills but also quite necessarily terminology. In North American contexts, we often encourage teacher interns to access not only Bloom's hierarchy of thinking but also to invoke classroom discussion patterns that use more thoughtful, engaging language (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Hunkins, 1989). This is clearly a difficult task in an ESL classroom.

Studies have shown that integrated curriculum can be successfully implemented with verifiably positive performance results (Hartzler, 2000). It remains however, that stakeholders across the Chinese system must somehow be convinced that situating learning in meaningful contexts, with active conceptual engagement, will promote better retention of ideas and learned students that can problem solve in the working world they are about to enter.



Gregory Mackinnon, PhD is a Professor of Science and Technology in the School of Education at Acadia University, Nova Scotia, Canada. His research includes studies of the impacts of technology on classroom instruction and the development of science and technology curriculum.



Kate Greene is a native of Cleveland, Ohio and a graduate of Barnard College. She worked as an ESL teacher at the Xin Qing Hua Pacican International Studies School during the 2015-2016 school year. She currently does Chinese-English translation and editing work in Beijing.



Edward Thomas Rawn was born in Ontario, Canada in 1981. He received a B.A in English and a Bachelor's degree in Political Science from McMaster University, Ontario, Canada in 2005. He began teaching English as a Foreign Language in China in 2008, and is currently the Director of Curriculum Research and Development at Pacican International Education and Cultural Services in Shanghai, China.



John Cressey is an educator from California, USA, living and working in Shanghai, China. He studied Linguistics and Cognitive Neuroscience at the University of California, San Diego. Currently, he is the co-chair of the English Department at Shanghai Xin Qing Hua Pacican International Studies School.



William He is the Vice-president of Xin Qing Hua Pacican International Studies School. Outside of his role in communications and student recruitment, his responsibilities include English and Science curriculum design and implementation. He graduated from Simon Fraser University with a Bachelor's degree and completed his Masters of Education degree at Pacific University.

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