



**Asia-Pacific
Economic Cooperation**

**Secondary Math and Science
Teacher Preparation: An
International Study of Promising
Practices in APEC from Economies'
Case Studies**

Human Resources Development Working Group

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HIGHLIGHTS

SECONDARY MATH AND SCIENCE TEACHER PREPARATION: AN INTERNATIONAL STUDY OF PROMISING PRACTICES IN APEC FROM ECONOMIES' CASE STUDIES

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PROJECT PARTICIPANTS:

Project Steering Committee

New Zealand: Alister Jones

Singapore: Sing Kong Lee

United States: Cheng Davis

United States: Alan Ginsburg

United States: Rebecca Maynard

Section Authors by Economy

Australia: Deborah Corrigan

China: Xu Binyan and Zhu Yan

New Zealand: Beverley Cooper and Bronwen Cowie

Russia: Nikilay Konstantinov, Petr Sergeev, Ivan Vysotskiy and Ivan Yaschenko

Singapore: Wong Khoo Yoong, Tan Kok Siang, Lee Ngan Hoe and Darren Wong

Thailand: Inprasitha Maitree, Srisawasdi Niwat and Thinwiangthong Sampan

United States: Alan Ginsburg, Sherri Lauver, Rebecca Maynard, Eileen Murray and Jon Star

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Project Steering Committee Foreword

Committee: Cheng Davis (Chair, Columbia University, USA), Alister Jones (University of Waikato, NZ), Sing Kong Lee (National Institute of Education, Singapore), Alan Ginsburg (U.S. Ed Dept-Retired, USA), and Rebecca Maynard (University of Pennsylvania, USA)

This project was stimulated by three important developments. The first is shifts in economies worldwide that have raised the importance of math and science skills to economic success locally and globally (Levy and Murnane 2004; OECD 2007; Peterson et al. 2011; National Research Council 2012). A second development is the recognition that math and science education programs in most Economies are failing to keep pace with the rising skills demands (National Research Council 2008). A third development is the recognition that stronger systems are required to recruit, prepare, and support math and science teachers (Hanushek and Woessmann 2013; National Research Council 2010a & b, 2011; Schmidt et al. 2007).

This project focuses on a case study approach in selected teacher training institutions in seven Economies. It is an attempt to broaden and deepen our understanding of what constitutes critical knowledge and skills for effective teaching of math and science at the secondary education level, how critical knowledge and skills can be developed by pre-service teachers, and how to support teachers effectively once they are in the classroom. Importantly, there is considerable diversity across Economies, as well as within Economies, in terms of the success of secondary education systems in turning out graduates who have the skills to contribute to sustainable economic and social growth (Carnevale et al. 2010; OECD 2013; Wai et al. 2010).

There is widespread recognition of the importance of teachers, and teacher quality, as a crucial factor in increasing students' engagement and achievement in mathematics and science. Yet there also is considerable diversity in the strategies used in various Economies to recruit individuals into the math and science education field, to prepare them to be effective math and science educators, and to support them to meet teacher standards of performance once they enter the classroom. There is a modest body of research examining the recruitment, preparation, and outcomes for primary school teachers (Blömeke et al. 2011; Kleickmann et al. 2013; National Research Council 2010b; Schmidt et al. 2007). However, there is much less information about the practices of different Economies for recruiting, preparing, and supporting secondary math and science

teachers and about the relationships between these practices and student outcomes.

This project represents a unique collaboration that brought together seven Economies (Australia, China, New Zealand, Russia, Singapore, Thailand and the United States) to identify promising and transferrable strategies for enhancing recruitment, preparation, and induction of novice secondary math and science teachers. Along this journey of cross-Economy collaborative and comparative research, the participating Economies have shared myriad details of their local contexts, strategies, accomplishments, and challenges. The participants maintained a spirit of informing our collective understanding of educational needs, constraints, and opportunities for improving math and science education practices and outcomes within the context of each of the participating Economies.

This group of Economies is diverse in social, economic, and educational governance systems and outcomes. For example, it includes highly developed and less developed economies and Economies whose students are among the highest performing in math and/or science and some who perform relatively poorly (Gonzalez et al. 2008; OECD 2007). It includes some of the world's largest and most rapidly developing economies— contexts that are relevant to the interests of both developed Economies, such as the United States, seeking to remain competitive in an increasingly global world, and to developing Economies, such as Thailand. Moreover, the nature of the teacher preparation programs varies across Economies and in ways that have been linked to student outcomes (Blömeke et al. 2011; Ingersoll 2007; Kleinmann et al. 2013).

The proposal for this project was first presented to APEC in January 2008 at the APEC Xi'an Symposium. Subsequent meetings of the working group occurred in June 2008 (University of Pennsylvania, USA), April 2009 (East China Normal University, China), November 2010 (University of Waikato, New Zealand), October 2011 (NIE, Singapore), February 2012 (Moscow Institute of Open Education, Russia), and November 2012 (U.S. Department of Education, USA).

Driven by Universities from both Western and Eastern Economies, the project was grounded within a strong research tradition of rich, case study research. The case study approach provided a depth of context that enabled particular outcomes to be more readily highlighted, and meant that comparisons could take into account the different educational systems. By involving policy makers, practitioners and academics, we have managed to bring additional depth to the

case studies. The approach was intended to identify both the strengths and the performance challenges of different Economies, to promote collective learning and application of those learnings to strengthen teacher education across APEC Economies. The strength of the collaboration resided in the commitment and enthusiasm of the participating research teams, and APEC's endorsement of the project.

Cross-cutting themes that emerged from the work include the importance of collaboration between teacher education institutes and secondary schools in the design and development of mechanisms for developing pre-service and beginning teachers' nascent pedagogical content knowledge (PCK), the benefits of embedding research within pre-service teachers' education as a means of strengthening the research-practice nexus, and the potential for Information and Communication Technologies (ICTs) to transform teacher education as well as teaching. Cross-economy assessment tasks to evaluate pre-service teachers' areas of strength in both content knowledge and pedagogical content knowledge were piloted. Further developing these innovative assessment pilots offers an exciting avenue for ongoing work. It would also be valuable to examine in-depth mechanisms for the systematic evaluation of teacher preparation programmes.

We offer this report in the hope that it contributes to ongoing development of math and science teacher preparation at the policy, programme and research level.

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Chapter 1. Implications for Practice: How to Use These International Findings To Evaluate and Improve Your Secondary Math/Science Teacher Preparation Program

A compilation from all the study authors

The findings from this university-based, cooperative, international research project identify potentially transferable practice comparisons. This project and its findings support the Education Ministers' call for university-based Asia-Pacific Economic Cooperation (APEC) collaborations.

“The Ministers applaud the growth of university-sponsored projects that bring together consortia of universities such as Mathematics and Science Lesson Study led by Khon Kaen (Thailand) and Tsukuba (Japan) universities, Foreign Language Lesson Study led by Ming Chuan University (Chinese Taipei), ALCoB co-supported by Pusan National University (Korea), teacher preparation in mathematics and science secondary education quality projects led by National Institute of Education (Singapore), Columbia University (United States), and the University of Waikato (New Zealand), and higher education quality projects led by Monash University (Australia), East China Normal University (China), the University of Hawaii (United States), and Far Eastern Federal University (Russian Federation).”

5th APEC Education Ministerial Meeting Joint Statement
May 2012, Gyeongju, Korea

Our results from this international project describe teacher preparation practices, based on case study findings, in seven different APEC Economies: Australia (AUS), China (PRC), New Zealand (NZ), Russia (RUS), Singapore (SIN), Thailand (THA) and the United States (USA). One application of these descriptions is for an institution or Economy to compare its teacher preparation practices with those this report found especially promising across the participating APEC Economies. These promising practices are the outgrowth of case studies carried out by university researchers in these Economies. In smaller Economies, such as New Zealand and Singapore, the case studies approximate common practice. In larger and varied Economies, such as China and the U.S., the case studies represent promising practices from specific institutions within the Economy.

One interesting finding about the context of teacher education systems emerging from our case study comparisons is that although Western systems are decentralized without standards for teachers, this has been changing in recent years. Economy organizations representing state policymakers and teachers have released voluntary or model teacher standards for state and local adoption (see CCSSO, NBTS) in the United States.

The practices described below are presented as promising in the sense of being identified with research and/or good management practice by the researcher/s in that Economy. However, their likely effectiveness has to be judged within each Economy's particular education, policy and performance contexts.

Comparison Practice 1. Teacher preparation institutions need to recruit sufficient numbers of quality preservice students to meet the demand for math and science teachers.

Teacher preparation institutions offer financial incentives to encourage enrollment of able students.

- PRC and SIN offer incentives, including free tuition and stipends while attending preservice teacher preparation.

Teacher preparation institutions have selective entrance requirements to accept more able students.

- NZ and SIN generally require a preservice entrant to have completed a prior math/science degree.
- PRC has a highly selective test-based entrance process.

Economies achieve an adequate supply of secondary math and science teachers through using a combination of rigorous selection criteria or licensing tests (where administered) and incentives to become a secondary math/science teacher.

While all Economies face some shortages in secondary math/science teachers, based on a 2012 Program for International Student Assessment (PISA) survey of secondary school principals, SIN and USA principals indicate their program of instruction is “least hindered by a lack of qualified” secondary math/science teachers.

- SIN draws from the top third of high-school grade-point average achievers and offers extensive incentives, while also requiring a prior math/science degree.
- The USA has a more open secondary teacher entrance process, but teacher education school graduates in most states have to pass a rigorous secondary math teacher licensing test. Those who pass the test average in the top 20 percent on the USA Scholastic Aptitude college entrance test.

Comparison Practice 2. Beginning teacher standards should drive teacher preparation coursework and evaluation of effectiveness.

Both traditionally centralized Eastern education systems and historically decentralized Western systems are beginning to look more and more alike as Western education associations broadly make available voluntary teacher standards for state and local adoption. Common to these teacher standards is a focus on teacher knowledge, teacher skills, teacher values, and teacher professional engagement.

- AUS's teacher standards come with an online companion set of extensive exemplar videos to illustrate good practice at different levels of teacher proficiency. Thus, the AUS teacher standards encourage and support continuous teacher progress to reach higher levels of teacher proficiency.
- SIN's teacher education model for the 21CC (TE21) includes a V³SK (i.e. values, skills and knowledge) framework and calls for 21st century teacher educators.

Comparison Practice 3. Preservice math/science teachers should develop deep content and pedagogical content knowledge (PCK).

Case studies of teacher education programs in all the participating Economies include courses about discipline content knowledge (CK) and pedagogical content knowledge (PCK), but the scope and sequence of these courses differ considerably. For example, Asian Economies' teacher preparation programs that were studied tended to stress teacher-preparation coursework related to mathematical and science content while Western Economies' programs found in the case studies emphasized coursework related to general pedagogy, psychology, and the teaching practicum.

Content Knowledge (CK): Future teachers need to learn tertiary math and science concepts and applications.

- In all the Economies with concurrent preservice systems (i.e., teacher training institutions offer math & science content and pedagogy courses at the same time), preservice secondary math/science content courses are taken in the math/science department and aligned with those of math/science degree majors.
- Math/science teacher preparation coursework should align with math and science content standards for secondary students. In the five Economies where Economy or voluntary/model content standards for secondary students were available (AUS, NZ, PRC, SIN, and USA), these content standards emphasized real-world digital applications of math and inquiry applications of science.
 - PRC’s math courses analysed in the case studies include a focus on mathematical applications (e.g., combinatory and graph analysis and mathematical modelling).
 - AUS’s preservice science teacher coursework examined in the case study has an explicit focus on learning and teaching about scientific inquiry.
- Tertiary math/science content should be integrated with the math/science content taught at secondary school.
 - The USA’s case-study curricula, UTeach model developed at the University of Texas and used in over 30 university teacher preparation programs, makes the connection between tertiary and secondary math and science content.

PCK: Preservice programs should prepare future teachers to teach math/science content at the secondary level.

Preservice teachers should learn to:

- Address the needs of diverse learners.
 - In RUS case study, “pedagogy of discoveries” is a teacher preparation program that provides future teachers with hands-on school experience, teaching gifted secondary math students.
- Teach real-world applications of math/science.
 - PRC case studies showcased the teaching of “mathematical competitions” and “problem solving strategies” for solving different categories of secondary mathematics problems.
- Understand how to use assessments and feedback to improve instruction.
 - SIN’s NIE course, “Understanding How To Develop, Use and Interpret Assessments,” employs a university-school collaborative to develop the assessment literacy of future chemistry teachers through preservice students creating, applying and analyzing paper-and-pen test items.

The practicum should provide future teachers with sufficient classroom time to gain real-world experience in applying what they have learned in the classroom.

- From the case studies used in this project, U.S. and NZ students spend about 50 percent more time in practicum teaching than do their Asian counterparts.

Comparison Practice 4. Assess discipline content and pedagogical content knowledge in teacher education coursework and use results to improve courses.

- USA researchers piloted a CK test for tertiary mathematics to assess preservice teachers' content and pedagogical knowledge.
AUS and USA researchers piloted pedagogical content knowledge assessments in science and math respectively. Singapore piloted the science assessment while China, New Zealand, Russia, Singapore, and the United States piloted the math assessment.

Comparison Practice 5. Future teachers need to learn to apply their knowledge by observing and teaching in carefully monitored real-world situations with expert feedback.

Teacher as researcher: Future teachers learn to research their own teaching to improve performance.

- AUS's chemistry course, "Science Teacher as Learner," reviewed in the Australian case study has teachers set their own aims and assess and improve their progress using such approaches as learning logs and portfolios, along with a framework for tracking preservice teacher development.
- THA's lesson study activities found in their case study combines learn-by-doing with a systematic collaborative review process.
- Teachers in PRC's MED program embedded in the teacher training institution case study they highlighted must complete a thesis of at least 20,000 words and defend it to a panel.

Preservice practicum: A rigorously supervised practicum supports future teachers to learn the core teaching skills of lesson building, classroom management, lesson delivery and student assessment.

- SIN's rigorously designed practicum is supervised by carefully chosen cooperating teachers working with a School Coordinating Mentor with a well-designed feedback rating form (Assessment of Performance in Teaching Instrument) and supervised at the National Institute of Education (NIE) by mathematics/science educators and/or discipline experts.

Teacher induction: A well-designed, supportive teacher orientation should foster a career-long learning orientation.

- AUS, PRC and NZ teacher preparation programs require induction for full-teacher registration as an Economy policy.
- NZ's induction program includes requirements for systematic (e.g., formal written induction processes), comprehensive (e.g. trained monitors drawn from the best teachers), multiyear induction with feedback to the preservice institution.
- SIN provides school-based and intensive mentoring to evaluate and improve new teachers during the first year of teaching before fresh graduates are confirmed in their position.

Assessing outcomes of teachers by applying their skills in real-world situations. Case studies from the various Economies emphasize that:

- THA conducts an independent review of preservice teachers' lessons.
- PRC requires future teachers to prepare a 20,000+ word written thesis defense.
- NZ's review of teacher induction includes explicit assessment of teacher portfolios.
- SIN and NZ have systematic mentor/expert reviews of teaching performance on a multidimensional rating form.

Comparison Practice 6. Teacher preparation institutions need to effectively prepare future teachers to use instructional technology.

Teacher preparation institutions found in the case studies effectively prepare teachers to use technology to deliver instruction.

- NZ's provisionally registered teachers have access to web resources, such as past examinations and assessments, and create their own individual electronic reflective portfolio.

- SIN's pedagogical tools bring the classroom into the university by using technology to simulate school learning environments, facilitating innovative pedagogies in re-structured tutorial rooms.

Teacher preparation institutions should effectively expose future teachers to using technology as instructional tools to teach secondary math/science.

- THA's technological pedagogical content knowledge (TPACK) show cased in the teacher preparation institution case study, prepares teachers to conduct inquiry-based science lessons using computer-based laboratories and simulations.
- SIN's preservice math teachers learn how to use math-based software such as Geometer's Sketchpad to teach geometry and algebra topics.

Comparison Practice 7. Teacher preparation institutions need to use information on the effectiveness of teacher preparation processes and outcomes to continuously improve the quality and effectiveness of their programs.

- The East China Normal University (ECNU) case study institution in China surveys graduates to monitor the quality of teacher preparation.
- NZ, as an Economy, requires annual approval by the Committee for University Academic Programmes (CUAP) (a subcommittee of Universities of New Zealand), and every second year there is an independent report by monitors appointed by the NZ Teachers Council.
- Singapore's NIE pursues continuous improvement, detailed in its implementation report, "NIE's Journey from Concept to Realisations," on its Teacher Education Model for the 21st Century (TE21). Setting-up the Office of Strategic Planning and Academic Quality spearheads evidence-informed academic quality enhancement efforts.
- USA teacher preparation institutions used in the case study analysis report teacher pass rates on state licensing exams. Some U.S. states are also piloting and conducting research on value-added estimates of teacher institutional providers.

Potential Future APEC Work on Teacher Preparation

- **Examine in depth how teacher preparation institutions systematically evaluate their effectiveness and use this information to improve.** Although not a major focus of this case study analysis, this project nonetheless

identified some practices that teacher preparation institutions introduce to assess program effectiveness and how they use this information to improve preservice practice. The issue of how best to evaluate and continuously improve teacher preparation effectiveness is a common concern of many APEC members, and a more in-depth look at these practices could be informative.

- **Follow up and further develop this project's innovative assessment pilots undertaken by AUS and USA researchers to assess secondary preservice teachers' knowledge of content and pedagogy in math and science.** This project recognized the importance of assessing secondary preservice teachers' content and pedagogical knowledge through two innovative pilot assessments in math and science. While the initial pilot results were promising, the instruments need further development prior to full application.

Chapter 2 Highlights: Purpose and Methodology

Alan Ginsburg (US Department of Education, Retired), Sherri Lauver (Synergy Inc., USA) and Rebecca Maynard (University of Pennsylvania, USA)

Purpose

This report supports the efforts of the Education Ministers in the APEC regions to continuously improve the quality of future math and science teachers by providing international evidence describing current, unique and promising practices in teacher preparation institutions and, in some cases, systems. The 2012 Joint Statement of the APEC Education Ministers specifically highlights the central importance of teachers and teacher preparation:

“We recognize the importance of teachers, and teacher quality as the most important factor determining students’ success.”

Developing new research on teacher preparation in secondary math and science education is particularly appropriate at this time because of:

- Recent research evidence suggesting that “better data on teacher preparation could aid efforts to improve education” (US National Academy of Sciences, 2010).
- The need to imbue in all students the skills that are necessary for success in a 21st Century digital economy that rewards strong math and science skills.
- 21st Century secondary math and science teachers need to reach all students, not just the highest-performing students.
- The need for teachers to emphasize real-world learning in mathematical applications and inquiry in science to support new 21st Century skills and align with secondary math and science content standards of their Economies.
- The need for teachers to prepare for classrooms in which instructional technology and data feedback radically alters teaching practice as students increasingly receive core instruction through technology using such transformations as flipped classrooms, mathematics and science simulations, individualized performance-tailored instruction.

In addressing these trends, this report fills an important knowledge gap in current comparative teacher-preparation practice internationally. While there have been previous studies of primary and middle school mathematics teacher preparation

activities, there has not been a major international study of secondary math or science teacher preparation.

Research Participants

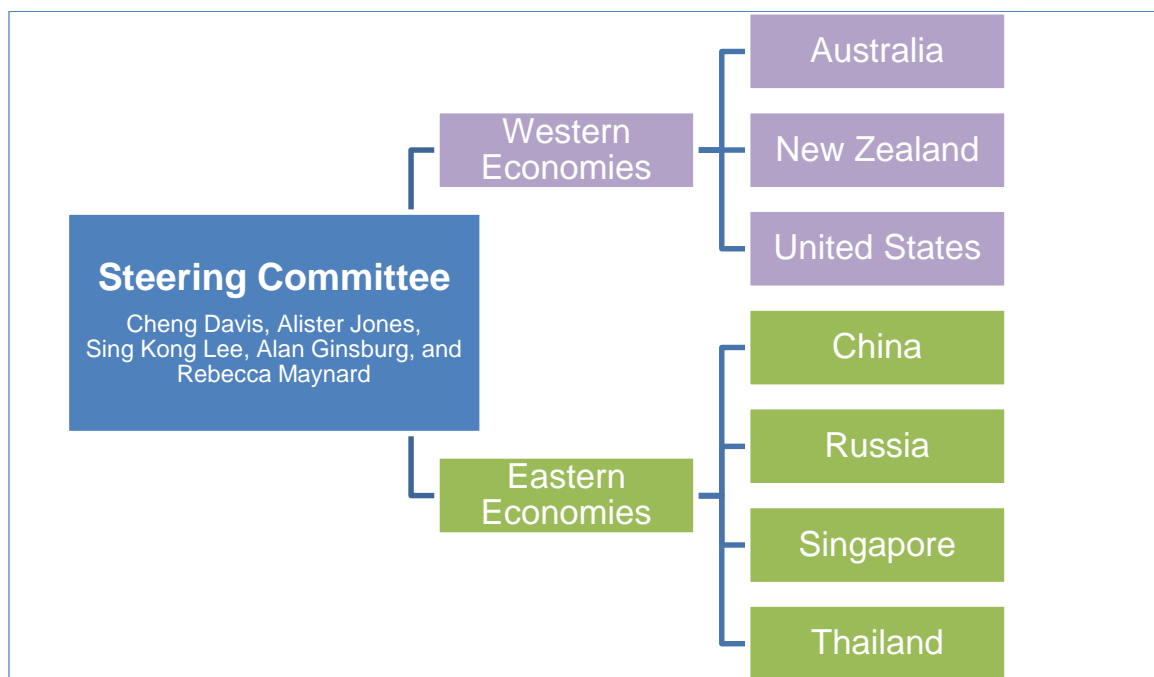
Researchers for this report, came together to form a collaboration from seven universities, with each forming separate Economy Research Teams. Four non-Western education systems were represented:

- PRC: East China Normal University
- RUS: Moscow Institute of Open Education
- SIN: National Institute of Education
- THA: Khon Kaen University

Five universities were from three Western Education systems:

- AUS: Monash University
- NZ: University of Waikato
- USA: Columbia University, Harvard University and University of Pennsylvania

Exhibit 1. Collaboration of 7 APEC Economies - East and West



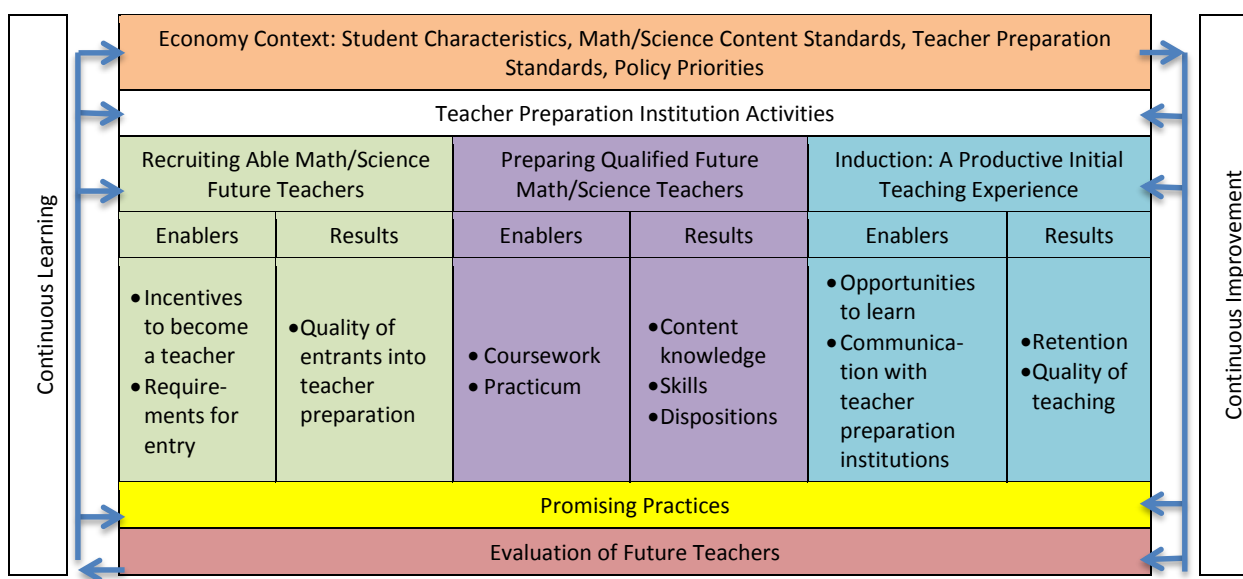
Goals of the Research on Secondary Math/Science Teacher Preparation

The focus of the project is to identify comparative teacher preparation practices that support:

- Strategies for creating a strong teacher workforce in secondary math and science through high-quality teacher preparation.
- Aligning teacher preparation coursework with secondary students' current math and science content standards. These modern content standards for secondary mathematics emphasize real-world digital applications, inquiry-based science and incorporating instructional technology as a major new teaching tool to enhance and individualize instruction.
- Strengthening teacher preparation to support equity of access and opportunity for secondary students.
- Supporting continuous improvement in teacher preparation coursework through assessment of preservice students' CK and PCK.
- Connecting teacher preparation programs to recruitment and in-service support systems.

Framework and Organization of the Report

Exhibit 2. High-Level Secondary Mathematics/Science Teacher Preparation Framework



The research framework in Exhibit 2 is organized around four aspects of teacher preparation: context, teacher preparation institutional activities, promising practices and evaluations of future teachers.

The research strategies in this project adopted different methodologies, as appropriate, to address the framework topics and research questions:

- Existing documents were used to describe current contextual factors, including teacher preparation standards.
- Common surveys of teacher preparation institutions were the primary source of information about recruiting, curriculum and teacher preparation challenges.
- Pilot assessments were designed as indicators of future teachers' knowledge of mathematics and science for teaching.
- In-depth case studies described secondary teacher preparation in mathematics and science and the context of teaching.

Looking Ahead, What Types of Practices Will Be Examined in Particular Participating Teacher Preparation Institutions?

The following illustrations highlight a few interesting features of the teacher preparation programs in institutions responding to our survey. Note, while they are not representative of the system in which they operate, they illustrate features that receive special emphasis within the institutions surveyed.

- AUS stresses teachers as self-learners through such means as teachers keeping time logs and conducting research on their own teaching.
- The PRC teacher preparation program emphasizes rigorous in-depth understanding of mathematics and science content and real-world applications.
- NZ stresses that prospective teachers must learn how best to teach students from different cultural backgrounds.
- RUS seeks to prepare a set of teachers who are able to develop the talents of the most mathematically and science-able students.
- SIN's rigorous teacher preparation programs are based on a tripartite collaboration among NIE, Ministry of Education, and schools such that fresh graduates are qualified to teach without further certification.
- THA focuses on employing lesson study to mathematics problem-solving.
- The USA has some teacher preparation institutions that are embarking on the combined teaching of mathematics or science content and the pedagogy to teach that content within the same course, rather than through traditional separate courses.

Chapter Organization

The chapters following this introduction explore Economy teacher preparation practices around the Exhibit 2 framework.

- Chapter 3: Economy Profiles
- Chapter 4: Recruiting and Training New Teachers
- Chapter 5: Case Studies of Promising Teacher Preparation
- Chapters 6 and 7: Evaluation of Future Teachers in Mathematics and Science Knowledge for Teaching
- Chapter 8: Teacher Induction

Chapter 3 Highlights: Economy Profiles

Alan Ginsburg (US Department of Education, Retired) and Rebecca Maynard (University of Pennsylvania, USA)

Secondary math and science teacher preparation takes place within different education contexts that affect what and how teacher preparation is provided. The Economy profiles explore the following education system characteristics that directly influence teacher preparation: student characteristics, math/science content standards, teacher preparation standards and policy directions.

The distinctions are narrowing between economies that traditionally have had centralized content standards for K-12 math and science courses, as well as teacher preparation standards, and those that have not.

For example, centralized Eastern systems, including PRC and SIN, are allowing greater student discretion over coursework. At the same time, the traditionally decentralized Western Economies of AUS, NZ and the USA are now characterized as debating or implementing voluntary or model content standards and teacher standards. Australia and New Zealand now have primary and secondary content standards and U.S. states are debating model content standards. Model professional teacher standards have been developed in a consortium fashion often prepared and overseen by a non-central government entity (e.g., organizations representing teachers or states) and not the central education ministry.

Teachers in each economy have to be prepared to engage all students in a secondary math and science curriculum, which includes an emphasis on practical applications in math and inquiry in science to support 21st Century workplace skills.

- PRC's revised math content standards shift away from pure "reception, memorization and imitation" to also stress "autonomous exploration, hands-on practical cooperative exchange" and to "develop students' mathematical application awareness."
- SIN's science framework encompasses the practical roles of science in daily life, science in society and science in the environment, and its mathematics curriculum framework has problem solving (including daily applications and mathematical modelling) at its core.

- AUS’s science frameworks link content with applications. Examples include: “understanding the ways in which models and theories are refined; ... how physics knowledge is used in a wide range of contexts and informs personal, local and global issues; and scepticism and intellectual rigour to evaluate claims.”
- NZ’s primary and secondary math curriculum devotes about a third of its content standards to statistics at every grade span, emphasizing an inquiry cycle that places individual statistical tasks in the context of larger processes of research, discovery and communications.
- As many states in the USA move toward voluntary and common content standards through the Common Core, the secondary math standards found in them emphasize mathematical modelling using technology to analyse varying assumptions, explore consequences and compare predictions with data.

Teachers in all economies have to be prepared to meet the challenge of teaching a diverse student population in math/science, although the nature of the population diversity differs.

- PISA results in math show the greatest variability among student scores in high-performing Shanghai and SIN, along with NZ among the seven Economies. In science, NZ and SIN have the highest variability. It should be noted, however, that Shanghai and SIN have overall higher average scores than the other Economies in this study. As a consequence, the other Economies in this study have a much higher percentage of students in the low-performing PISA groups.
- Math and science content standards for secondary students recognize that all students, not just future engineers and scientists, need exposure to these subjects at secondary level; teachers need to be prepared to recognize the diverse needs and preferences of students.
 - PRC has revised its secondary math content standards to emphasize student coursework, including optional modules beyond their core educational content.
 - SIN science content standards cover two secondary groups – the more rigorous academic group, and the less rigorous technical group, which emphasizes familiar science application topics such as “gadgets work wonders”. Upper secondary students take one of three core math courses and the more able students may take an additional math course.

- AUS’s math and science curriculum has distinct modules and hierarchal pathways, allowing students to take different numbers of modules, with varying rigor within modules.
- NZ’s National Certificates of Educational Achievement (NCEA) has three levels to allow students to proceed at their own pace. Students also are able to demonstrate their achievements through multiple avenues of assessment measurements.
- Unlike other math content standards, the new USA Common Core math standards stress a homogeneous common core. The USA Common Core is concerned that a significant fraction of students are taking “watered-down courses which leave students ... unready for success in postsecondary courses or for entry into many skilled professions upon graduation”.

A quality and responsive teacher education program should prepare future teachers to meet teacher preparation standards for initial teacher education.

- Among the five Economies for which we have documented teacher standards, either Economy or voluntary/model teacher preparation standards, four Economies (SIN, AUS, NZ and the USA) address preparing teachers with the common aims of (1) knowledge, (2) skills/practices, and (3) professional engagement/values.
- PRC, the fifth system, is a developing Economy. Its teacher preparation standards place a great emphasis on appropriate teacher qualifications.
- Interestingly, the teacher standards of the two Eastern Economies stress teachers’ morals/values.
 - PRC calls for “always putting moral education in the first place”.
 - SIN strengthened their emphasis on values, calling for three categories: learner-centered values, teacher identity values and the values of service to the profession and community.

Teacher preparation standards found in each of the five Economies partially address three major emphases for teaching secondary math and science (Exhibit 3).

- All five showcased Economy teacher preparation standards address the need to prepare teachers for diversity among students through learner-centered instruction.
- Some Economies may want to address gaps in their various kinds of teacher preparation standards, which do not address preparing teachers to teach

school students real-world problem solving, foster independent learners or use technology as a teaching tool in the classroom.

Exhibit 3. Economy Teacher Standards Address Major Areas of New Emphasis

| | AUS | NZ | PRC | SIN | USA |
|------------------------------------------------------------------------------------------------------------------------------------------|-----|----|-----|-----|-----|
| Learner-Centered/Diversity | X | X | X | X | X |
| 21st Century Skills | X | | X | X | X |
| <ul style="list-style-type: none"> • Real-world problem solving • Independent learners with communication skills | X | | X | X | X |
| Using technology (online, computers) as a teaching tool | X | X | | X | X |

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Chapter 4 Highlights: Key Findings from Teacher Preparation Surveys

Xu Binyan, Zhu Yan and Zhuangyu Stella (East China Normal University, PRC)

In order to identify the essential characteristics of secondary teacher preparation programs in each participating APEC member economic, a survey questionnaire entitled “APEC Survey of Curriculum for Upper Secondary High School Mathematics/Science Teacher Preparation Programs” was first developed. The survey is comprised of five main themes, including type of institution, selectivity and entry requirements of students entering the teacher preparation programs, types of program, objectives of the program (math/science), and course information.

Each participating APEC member economy selected a small sample of different types of institutions based on an Economy’s individual’s unique context. With the exception of Singapore, which has a single teacher preparation institution, the survey responses describe interesting case studies that are not representative of an Economy’s teacher preparation institutions, as a whole. Specifically, more than 20 institutions from 12 economies responded to the questionnaire survey forming the basis for the case studies. As a follow-up, a more in-depth questionnaire on teacher preparation programs was further developed that looked into three aspects of teacher preparation process: recruiting and admissions, teacher preparation coursework, and quality of teacher preparation programs.

The following findings are drawn from the institutional case study surveys.

1. Recruitment Strategies: Two main strategies were identified for recruiting/attracting qualified student teachers among Economies, including financial support and job/further degree study offers.

To attract qualified students to enrol in teacher preparation programs, the survey identified two main strategies used by the Economies.

- One is to ease the financial burden of tertiary study.
 - SIN’s Ministry of Education provides a good remuneration package for teachers (starting pay of teachers is comparable to other professions), various types of scholarships and awards, waiving of tuition fees and full salary for the first 2 years of training.
 - Similarly, student teachers in both NZ and PRC may qualify for the Free-

Tuition Student Teacher Program. More qualified student teachers can also receive scholarships.

- The second strategy concerns student life after graduation from the teacher preparation programs.
 - In SIN, all qualified student teachers are treated as employees of MOE once they enter the program.
 - In PRC, the province-level Committee of Education offers graduated student teachers positions in their own provinces. Graduates may return to university to pursue their Master's degree without an entry exam after one year of work (under the Free-Tuition Student Teacher Program).

2. Special-Need Students: The USA tends to focus more on low performers whereas PRC and RUS pay more attention to high achievers.

Special-need students shall include both low achievers and high achievers.

- In PRC, high achievers receive more attention. For instance, one course offered in the Department of Math at East China Normal University (ECNU) is entitled "Principles of Mathematical Competition and Problem Solving."
- In RUS, Moscow universities provide highly qualified young mathematicians and prospective teachers with supervised opportunities to teach mathematically gifted students (13-17) attending School 57.
- In Australia, all teacher education courses must focus on the spectrum of special needs (from low achievement through to gifted for example) and provide evidence of how courses develop expertise in responding to differentiated learning needs of students.

3. Teacher Preparation Coursework: There is a strong subject-oriented student teacher training model in PRC while models of more general pedagogical training aligned with content occur in SIN and USA.

- In PRC, there is a subject-oriented student teacher training model. Candidates have chosen their major field of study (such as mathematics or physics) when entering university. This is related to the fact that each teacher has his or her own specialist subject in secondary schools. Based on their subject selection, student teachers have two kinds of courses in the program – content courses and general courses. For example, student math teachers at ECNU receive part of their content courses from the department of math (e.g., "Linear Algebra"), the department of education (e.g., "Case-Study Methodology" or "Classroom Management") and general courses from other school departments (e.g., "Psychology of Education" and "Art Appreciation").

- In SIN, discipline experts and the respective educators belong to the same department to facilitate alignment of training provided to future teachers about CK and PCK.
- In Australia, postgraduate courses provide subject specific pedagogical streams as all students have recognised disciplinary expertise prior to entry. In undergraduate courses, students take discipline specific study from Science/Math facilities and take subject specific pedagogical studies in the final year (4th year) of the programs.
- In the USA, teacher preparation institutions are using an innovative model to teach content and pedagogy simultaneously in the same set of courses.

4. Practicum Organization: There is greater time spent at school sites in NZ and USA compared with PRC and SIN.

- The practicum in SIN is about 10 weeks long, within a year-long program of 30 weeks. The practicum begins with students observing the cooperating teachers' lessons, followed by actual teaching from week 3 onward.
- The practicum in the USA teacher training institutions that were surveyed lasts at least 15 weeks at the school site, and student teachers are expected to teach one or two classes on their own each day under the direction of their supervising teachers.
- The practicum in NZ lasts about 14 weeks for a consecutive program and 20 weeks for a concurrent program, with the latter spread over 3 academic years.
- The practicum in PRC (ECNU case) consists of three phases, including a 1-week pre-practicum training at the university site, 10 weeks of practicum at the school site, and about 1.5 months post-practicum reflection back at the university site.

5. Feedback Providers: Student teachers receive feedback about their practicum performance from different parties, including universities, schools and/or a combination.

- In all the Economies, both the university and host school provide feedback to student teachers on their performance during their practicum, which could be regarded as a combined assessment.
- NZ puts particular emphasis on feedback from the university, whereas PRC emphasizes feedback from the school.

6. Quality Controllers: Different parties take charge of monitoring the quality

of teacher education, including universities or a third party.

- The case study universities in SIN, USA and PRC have their own systems to help monitor the quality of teacher education by administering surveys to their graduates at the end of the program.
- In Australia, all teacher education courses are accredited against a set of Economy teacher preparation program standards for teacher education and graduates and their employers are surveyed by the Federal government four months after graduation.
- In NZ, the New Zealand Teachers Council (NZTC) is responsible for monitoring via interviewing program leaders, academic staff, school principals and school teachers involved in the practicum, etc.

Chapter 5 Highlights: Case Studies of Promising Practices in Secondary Math and Science Teacher Preparation

Wong Khoon Yoong, Tan Kok Siang, Darren Wong and Lee Ngan Hoe (National Institute of Education, Singapore)

1. What we mean by “promising practices”

Teacher education programs in the participating Economies are complex and must align with specific Economy contexts, such as entry requirements, duration of training, systemic education goals and content standards for secondary students, quality of teacher educators and so forth. Nevertheless, these programs have strengths that may stimulate in-depth considerations by other Economies. Hence, the term “promising” was chosen to highlight future directions based on evidence of past implementation by the Economies that submitted case descriptions. These cases were not necessarily “best” practices, but they may be “unique” to the reporting Economies. Each promising practice represents a good practice within an Economy. The practice is a case study and hence is not necessarily representative of common practice across an Economy’s teacher preparation institutions.

2. Why share these promising practices?

The main aim of sharing these cases is to encourage key stakeholders to consider alternative policies and practices to improve teacher preparation programs within their own Economies by learning from diverse promising practices from the other Economies where evidence of impacts is available for reflection. The impacts of these cases may or may not be similar when the practices are implemented within different educational contexts. Reflection on these cases, when taken together with findings from the two sub-studies on “Economy Profiles” (Chapter 2) and “Teacher Preparation” (Chapter 3), are likely to lead to fresh possibilities that can be investigated.

3. How was information about promising cases collected?

Lead researchers agreed on a template about what to report in about 1500 words about their chosen cases, with the aim of shedding light on math and/or science teacher education practices. This template covered four areas: Title, Level (primary, secondary), Domain (mathematics, sciences, general) and Focus (e.g., PCK, assessment, ICT). The authors were to provide artifacts and evidence of the impacts of their submitted cases. This framework was found to provide succinct yet helpful information for the intended aim and might be used for similar future comparative studies.

4. Four major themes

The seven cases were found to overlap in common themes, four of which were:

1. Strengthen collaboration between teacher education institutes and schools (NZ, PRC, RUS and SIN).
2. Develop content and pedagogy knowledge (AUS, PRC, RUS, THA and USA), in particular, supervision of gifted students (RUS).
3. Include research in teacher education (AUS, NZ, PRC and THA).
4. Use ICT in training and teaching (AUS, NZ and THA).

Additional details can be found in Exhibit 4.

5. Future Work

The seven cases represent only a tiny tip of the complex iceberg of teacher education programs in the participating Economies. Yet they provide interesting glimpses of what can be learned from one another. Future collaboration among APEC teacher educators should focus on developing evaluation strategies that can demonstrate the effectiveness of selected practices. This component of the case reports was found to be lacking, possibly due to the constraint placed on the length of the report or that evaluations may be in progress. Evaluation strategies may be at the macro (Economy) meso (district, teacher institutes) or micro (individual educators and trainees) level, and both quantitative and qualitative data should be gathered. It is also important to situate and contextualize practices within the education landscape and the teacher education programs of the Economies. New insight about integration of these practices within the teacher preparation program can be gained by relating these cases to other chapters of this project.

Exhibit 4. Summary of Promising Practices

| Economy (authors) | Title | Level | Domain | Focus |
|----------------------------------------------|----------------------------------------------------------------------------------------------------|-------------------------------------------------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Australia (Deborah Corrigan) | Developing the notion of high-quality chemistry teaching in preservice chemistry teacher education | Preservice, final year course | Chemistry | This case describes a course at Monash University that is based on the notion of “science teacher as learner”. Future chemistry teachers set their own aims and use learning logs to record personal learning; in particular, how to integrate knowledge bases, skills, attitudes and values required to teach chemistry. Both chemistry teacher educators and future teachers use the same framework as co-learners. |
| China (Xu Binyan, Zhuang Yu) | In-service MED program for free-tuition normal-major graduates | In-service | General | This case explains how a Master’s-level program of 2.5 years duration is implemented for teachers to upgrade their qualifications through a free-tuition system. Courses are conducted during school holidays and via distance learning to enable teachers from remote rural schools to enroll in the program. Six normal universities are involved, and the program was first implemented in 2012. |
| New Zealand (Beverley Cooper, Bronwen Cowie) | Induction and mentoring | Induction for provisionally registered teachers (PRT) | General | This case examines systemic teacher standards and activities that are provided to help newly graduated teachers gain full registration as a fully qualified teacher with a 2-year, school-based, educative induction and mentoring program, first implemented in 2012. |

| | | | | |
|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Russia (Petr Sergeev, Nikilay Konstantinov, Ivan Yashchenko, Ivan Vysotskiy) | “The Pedagogy of Discoveries: Teachers Preparation Program” in Moscow State 57th Math School as an essential component of continuous mathematical education | Preservice | Math (calculus) | This case is specific to Moscow State 57th school. Future math teachers who excel in mathematics supervise small groups of gifted students (13–17 years old) to strengthen the formers’ roles as mathematicians and to learn about pedagogy under the guidance of experienced school teachers. This experience lasts for 3–4 years. |
| Singapore (Tan Kok Siang, Darren Wong) | Developing assessment literacy of future chemistry teachers through a school-university collaboration | Preservice | Chemistry | This case reports on a school–university collaboration to develop the assessment literacy of future chemistry teachers at the NIE. Future teachers develop assessment documents and paper-and-pen test items that are owned by the future teachers, the schools and the NIE. The goal is to strengthen theory–practice applications. |
| Thailand (Maitree Inprasitha, Niwat Srisawasdi, Sampan Thinwiangthong) | Good practice in teacher education program for mathematics and science preservice teachers at Khon Kaen University | Preservice | Math and science | Two cases are reported and they are part of a 5-year bachelor degree program. In the math case, an innovative framework covering PCK, lesson study, community of practice, learning by doing and reflective thinking is used to help future teachers learn to create problem solving classrooms and develop core values. The science case explains how future teachers learn to conduct an inquiry-based science laboratory through the development of TPACK. |

| | | | | |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>USA (Jon Star, Eileen Murray)</p> | <p>Content preparation course experiences for prospective secondary science and math teachers</p> | <p>Preservice</p> | <p>Math and science</p> | <p>Two different approaches are used to develop the content knowledge base of future secondary mathematics and science teachers under the UTeach model at the University of Texas at Austin. Future math teachers develop connections between secondary and tertiary mathematics, while future science teachers learn how new knowledge is developed in science within a lab-based research methods course. Special UTeach course textbooks are now used in over 30 universities.</p> |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Chapter 6 Highlights: Assessing Knowledge That Supports High Quality Math Instruction

Jon R. Star and Eileen Murray (Harvard University, USA)

Overview:

1. We developed assessments to measure prospective mathematics teachers' CK and PCK.

The development process of the assessments was iterative, with questions generated and feedback provided by all Economies. The final assessments include a 45-minute PCK assessment and a 30-minute CK assessment. We also created a scoring rubric for the assessments.

2. Economies administered the assessments. Economies were asked to translate the assessments and then administer them to a convenience sample of prospective secondary math teachers. The convenience sample is a non-probability sample that was drawn from students in one or several highly-regarded teacher preparation institutions within each participating Economy.

Standardized instructions for administering the assessments were provided, including the provision that no calculators were to be used, that the assessments were proctored and that the assessments were taken individually. Economies were asked to grade the assessments and report raw results to the USA.

3. Prospective secondary math teachers from the USA (n = 60), RUS (n = 31), PRC (n = 25), NZ (n = 3), and SIN (n = 56) completed one or both the assessments.

Note that comparison of results should be undertaken with caution because (among other reasons) of the convenience sample of teachers taking the assessments. In addition, the assessments were not intended to be comprehensive in their coverage of CK or PCK. Further, fewer students across all Economies took the CK assessment; in most Economies, teachers only had time to take one assessment, and the focus was on the PCK assessment.

4. There were several interesting findings from the assessment administration.

First, performance on both assessments was more similar than different. The average item-by-item performance on both CK and PCK was similar for all Economies. Second, teachers by and large struggled with the items on both

assessments. Prospective teachers generally did not show strength in CK, despite the fact that most were in the final stages of completing an undergraduate degree in math. Teachers did not perform especially well in PCK, either.

5. Further work can be done

Further work is needed – to more broadly administer these assessments, to continue to validate them, and to then consider ways in which comparisons between different types of teacher education programs can be made.

Background

A central goal of teacher education programs across the world is to provide prospective teachers with the knowledge necessary for supporting high-quality instruction (content knowledge, or CK). Ever since Shulman's (1987) seminal work on PCK, researchers and practitioners have also sought to investigate how teachers can teach this content in ways that are comprehensible to their students. Mathematics CK refers to a teacher's knowledge of mathematics and its organizing structures. PCK in mathematics refers to the knowledge necessary to teach mathematics and consists of two components: knowledge of instructional strategies/representations and knowledge of students' preconceptions and misconceptions in mathematics (e.g., Bolyard & Moyer-Packenham, 2008; Hill, Rowan, and Ball, 2005; Piccolo, 2008). Within the context of the present project, our goal was to create a short math assessment that could provide information about prospective secondary math teachers' knowledge at the conclusion of a teacher preparation program.

The Assessments

Our assessments were initially created by a small group of experts in math education and mathematics, with minimal piloting, but with several rounds of input by representatives from participating Economies. Each Economy was provided with copies of the CK and PCK assessments in English, as well as grading rubrics for grading each assessment. Where necessary, translation was conducted by representatives from each Economy. Economies were asked to administer the assessments to a small group of prospective teachers. When time permitted, we asked Economies to administer both the CK (30 minutes) and PCK (45 minutes) assessments; when this was not possible, we asked for the PCK assessment to be prioritized. Economies were asked to grade all completed assessments and report results to the USA project team.

On the Interpretation of Results and Comparison of Economies

Although we are satisfied with the assessments that we have created, we also recognize that there are limits to the conclusions that can be reasonably drawn from the results of our assessments. First, comparison of results across Economies should be undertaken with caution. No claims can be made about representative sampling of prospective teachers or institutions, security of the assessments prior to administration, uniform test administration or adherence to the provided grading. Thus, we believe that the results of the math assessments will be most useful and valid within each Economy. Second, we urge caution in making broad claims from the assessment results about teachers' PCK in general or teachers' advanced math knowledge in general. Together, the two assessments include only a few PCK and CK items. The assessment results should be interpreted at an item-by-item level, not at a construct level.

Results

Students from the NZ, PRC, RUS, SIN, and USA completed the assessment. Below we report in brief the results from each of these Economies.

United States. In the USA, a convenience sample provided us access to 60 students who took the assessment across six universities. Of the eight PCK items, USA students on average correctly answered 1.58 items ($SD = 1.48$); scores ranged from a low of 0 correct to a high of 5 correct. On the CK test, of the seven CK items, USA students who attempted this test on average correctly answered 1.62 items ($SD = 1.42$), with a range of 0 to 4 correct. On both tests, the modal number of correctly answered items was 0.

Russia. In RUS, a total of 31 students participated in the study. Few Russian students attempted items on the CK assessment, so we report only the results from the PCK assessment. Of the eight PCK items, Russian students on average correctly answered 1.97 items ($SD = 1.43$); scores ranged from 0 to 5 correct, with a mode of 1.

China. In PRC, 25 students participated in the study. Of the eight PCK items, Chinese students on average correctly answered 1.96 items ($SD = 1.02$); scores ranged from 0 to 4 correct, with a mode of 2. On the seven-item CK test, Chinese students on average correctly answered 2.32 items ($SD = 1.89$), with scores ranging from 0 to 7 correct, with a mode of 1.

New Zealand. Three students from NZ participated in the study by taking the CK and PCK tests. Student 1 correctly answered two PCK items and six CK items;

student 2 correctly answered four PCK items and three CK items; student 3 correctly answered two PCK items and two CK items.

Singapore. In SIN, 56 students participated in the study. Of the eight PCK items, Singaporean students on average answered 2.73 items ($SD = 1.24$), with a range of 1 to 5 correct and a mode of 3. On the seven CK items, Singaporean students correctly answered 1.68 items on average ($SD = 1.51$), with a range of 0 to 6 correct items and a mode of 0.

Conclusions

Based on these results, we arrived at the following tentative conclusions.

1. Items were collaboratively developed and seemed a reasonable collection that tapped into what was desired of prospective teachers' PCK and CK. Yet, prospective teachers by and large struggled with the items.

With respect to PCK, it is perhaps not surprising that performance on PCK items was relatively low. Despite possible efforts to address this type of knowledge in coursework, perhaps it is reasonable that we found prospective teachers to be lacking in PCK. Future work can consider administering the PCK assessment to more experienced teachers, to see whether increasing experience leads to higher PCK scores, as might be predicted.

With respect to CK, students' performance was also generally low. Despite their recent completion of an undergraduate degree in mathematics, participants in all Economies generally had difficulty completing these CK items. Questions could be raised as to the importance (for secondary teachers) of mastery of the undergraduate mathematics curriculum, but the fact remains that these prospective teachers across several Economies generally did not show strength in CK constructs that were assessed.

2. It is interesting to note that, looking across different Economies, performance on both assessments was more similar than different. That is, the average item-by-item performance on both CK and PCK was quite similar for all Economies.

3. However, again note that it is very difficult to compare across Economies, for many reasons. Further work can be done to more broadly administer these assessments, to continue to validate them, to assess the appropriate difficulty of assessments, and to then consider ways that comparisons between different types of teacher education programs can be made.

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Chapter 7 Highlights: Summary Document: Assessing Preservice Science Teachers' Content and Pedagogical Content Knowledge

Deborah Corrigan (Monash University, AUS), and Beverley Cooper and Bronwen Cowie (University of Waikato, NZ)

Overview

This chapter reports on a pilot administration, primarily in Singapore, of an innovative methodology to assess future science teachers' (1) content knowledge in the area of the nature of science; and (2) pedagogical content knowledge using a novel but highly reliable approach of Content Representations (CoRes). The survey questions and coding scheme were developed and provided by the Australian and New Zealand lead researchers.

Introduction

One of the four broad areas of teacher preparation improvement is to explore strategies for achieving high-quality teacher preparation that builds the requisite foundational knowledge and skills in future math and science teachers. Such foundational knowledge includes CK, pedagogical knowledge, PCK as well as knowledge of curriculum, learners, contexts and assessment. In this chapter, we were concerned with providing direct assessment evidence about how much prospective secondary science teachers know about content and pedagogy. Direct assessment evidence needed to be gathered across the seven participating Economies, in a relatively short time frame and across the science domains of chemistry and physics. Mathematics had developed a test of content, advanced content and pedagogical knowledge. Producing something similar across chemistry and physics was more problematic.

From the outset, preparing such a test goes against the very heart of professional-based teachers' standards, as they have been developed in AUS and NZ and other Economies such Canada. The evaluation of preservice, graduate and registered teachers in these Economies is based on teacher preparation standards where evidence, often qualitative in nature, in conjunction with supporting arguments, are provided regarding teachers' attainment of the teacher standards in a range of areas necessary for a professional teacher. These teacher standards require evidence that include CK and pedagogical knowledge.

In addition, the tradition in many of these Economies also views PCK, particularly in science, as an attribute of an experienced teacher, given that this knowledge domain requires the transformation of subject-matter knowledge for the

purposes of teaching (Magnussen et al. 1999, Shulman 1987). From this point of view, it is then not appropriate to expect preservice teachers to have developed any significant PCK due to their limited experiences, and consequently, it cannot be tested. However, this is not a view shared by all Economies who are members of this project, so a science assessment “test” was produced.

Assessing content knowledge

The difficulty with trying to assess content and PCK in science centers around the notion that this test would be for physics and chemistry preservice teachers. Hence, the only content area that overlaps for these students is in the area of the nature of science.

Assessing PCK

The existence of PCK of preservice teachers, let alone the testing of it, is a contested field. While many believe it is unproblematic, many also believe it to be highly problematic and inappropriate. In Shulman’s (1987) original ideas surrounding PCK, he stressed that it was about the transformation of subject matter for the purposes of teaching. Given the limited teaching experience of preservice teachers, there has been limited opportunity for the development of their pedagogical knowledge, let alone their PCK.

Part 2 of the science assessment builds on a significant research base around the development of PCK in science teachers. Leading this research has been Loughran et al. (2012), whose work in representing PCK has now reached across the globe and is generally well accepted. The use of Content Representations (CoRes) is part of their work, and they gave permission for it to be used in this test. CoRes are designed to scaffold the thinking that is required for respondents to begin to articulate their PCK. The questions within the CoRes focus on the respondents’ understanding of subject-matter knowledge in a particular field, the pedagogical experiences they have had and how such experiences have helped them to reconsider and reframe their understanding in this content area. Such thinking is difficult to undertake, particularly by an individual whose pedagogical experiences have been limited.

Therefore, when taking this test, it may be more appropriate that groups undertake this task rather than individuals. For this reason, the results of this test have not been used to assess individuals, but rather to gain insights into the CK and PCK of an Economy’s preservice chemistry and physics teachers.

The structure and parameters of the test

Part 1 of the test consists of a passage containing scientific information that presents students with several views that are mutually inconsistent, owing to different premises or differing interpretations of data. The test questions measure students' knowledge and skills in understanding, analyzing and comparing alternative viewpoints.

The second part of the test – the CoRes part – includes the following seven questions:

1. What do you intend students to learn?
2. Why is it important for students to know this?
3. What else do you know about these ideas (that you do not intend students to know yet)?
4. What are the difficulties/limitations connected with teaching this idea?
5. What knowledge about students' thinking influences your teaching of this idea?
6. What other factors have influenced your teaching of this idea?
7. What teaching procedures do you use? (Provide particular reasons for using these to engage with this idea.)

Obviously, questions 5 and 6 require some experience of having taught this content to students. Given this may not be the case for preservice teachers, they were not required to complete these two questions.

Concluding Remarks

The test has been piloted to be applicable across Economies. The scoring rubrics are also able to be implemented across Economies. In spite of the reservations associated with the development of a test of science CK and PCK highlighted at the beginning of this chapter, it appears that with the use of some well-established (within the science education research community) items and some innovative assessment methods, there is a great deal of potential for the use of this test in gaining insights in these knowledge domains of preservice teachers.

The development of this test, together with some encouraging responses (particularly from SIN) indicates that given the difficult challenges of matching content across different Economies and different disciplines within science, such as chemistry and physics, that further application of the test across Economies is possible and encouraged.

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Chapter 8 Highlights: Induction

Beverley Cooper and Bronwen Cowie (University of Waikato, NZ)

This chapter on induction programs reviews recent research, Economy policies, and promising practices based on surveys filled out by Economy researchers participating in this international study.

Induction programs are known to be variable in focus, quality and outcomes. Currently, induction of beginning teachers is focused on fostering career-long learning dispositions (Feiman-Nemser 2012). Typically they include activities such as school orientation, classroom support, workshops, mentoring and opportunities for collaboration with colleagues (Ingersoll and Strong 2011). However, even within the one school, beginning teachers' experiences can vary from supportive to challenging (Wechsler et al. 2010).

Ideally, induction is a systemic, comprehensive, coherent and multiyear professional development process that takes place within a supportive professional learning community that is ongoing throughout a teacher's career. Of the participating Economies, the SIN case has the most explicit focus on inducting beginning teachers into a nation-wide professional learning community via a required Ministry of Education Heritage Centre visit and non-mandatory school-based initiatives, such as onsite "research activist" lesson study groups and school clusters that have action research as a professional development activity. AUS and NZ are Economies where teaching as inquiry is being embedded system-wide into professional teacher standards and is an expectation for registration.

Mentoring by experienced teachers is a key element of most induction programs, and it impacts beginning teacher retention, job satisfaction and teaching practice. Mentoring needs to be an educative process where both the mentor and mentee are positioned as learners in the induction process. Educative mentoring is explicitly mandated as part of beginning teacher induction in NZ, where policy positions the mentor and beginning teacher as learners together (NZTC 2011).

Mentors need and benefit from support and training (Langdon 2013) and time to focus on their role. This is provided in AUS, NZ, PRC and RUS. Quality induction requires that school leaders sanction time for beginning teachers to be observed and reflect on their own teaching as well as on their students' learning (Darling-Hammond et al. 2009; Hudson et al. 2007).

Beginning teachers benefit from informal as well as formal mentoring, with informal mentors helping to address the tension between assistance and evaluation. Ingersoll and May (2011) report that beginning teachers need supportive school environments where they feel valued, trusted and empowered to collaborate for the purpose of improving instruction. Informal professional and personal collaboration can support reflection on practice to develop understanding of content, pedagogy and learners, enhance job satisfaction (Berry et al. 2010) and resilience (Papatraianou and Le Cornu, 2014). In Shanghai's experimental schools, for example, teachers are expected to engage in joint work to support their teaching. Beginning teachers are assigned senior teachers as their mentors to assist them in learning about and developing their practice in line with professional teacher standards. In RUS and PRC, beginning teachers observe lessons conducted by experienced teachers in their own school and other schools.

Subject-specific mentoring is advocated on the basis that the development of beginning teacher PCK is essential (Desimone et al. 2013). Induction programs with a focus on subject-specific pedagogy and beginning teacher participation in teacher networks in their specialized fields are useful in supporting beginning teachers' learning as envisioned within current curriculum (Luft 2009). Studies indicate that teachers who experience subject-specific support are more likely to remain in the profession (Smith and Ingersoll 2004). However, there is no definitive research evidence that subject-specific mentoring leads to higher student engagement and achievement.

Information and communication technologies can play a useful role in the induction process. External networks supported by online technologies can help reduce teacher isolation while providing access to a wider range of ideas and colleagues for reflection and feedback (Fulton et al. 2005). All Economies encourage the use of portfolios to illustrate teacher learning and development against various professional teacher standards. In many Economies, the internet and other media have become a major resource for teachers. In NZ, for example, the website Te Kete Ipurangi (TKI) has been developed by the Ministry of Education and houses a wide variety of teacher resources, including reading for teachers and curriculum and assessment information. In RUS, magazines published for mathematics, chemistry and physics teaching are dedicated to the development of class lessons, sharing teachers' experience and useful information for teachers.

Exhibit 5 summarizes the different induction processes in the Economies that participated in the study and allows for identification of different practices. For

example, the Western Economies of Australia and New Zealand have a common practice of mandating in-school mentors and portfolios, while the U.S., which can also be considered a Western Economy, leaves these processes to school-level decisions.

Exhibit 5. Key Elements of Economy Beginning Teacher Induction Processes

| Economy | Program type | Required for full teacher registration | Formal or informal | Time allowance | In-school mentor | Portfolio mandated |
|---------|-------------------------------------|----------------------------------------|--------------------------|------------------|-------------------------|-----------------------|
| AUS | State & school-based | Yes | Both Formal (1-2 yrs) | Yes | Yes | Yes |
| PRC | Regional & school-based | Yes | Both Formal (4 yrs) | ? | Yes (Initial 1-2 years) | No |
| NZ | School-based | Yes | Both Formal (2 yrs) | Yes | Yes | Yes |
| RUS | School-based | No | Both Formal (4 yrs) | ? | Yes | No |
| SIN | Economy (Compulsory) & school-based | No | Both Formal (2 yrs) | School-dependent | Yes | No |
| USA | Variable | No | Formal in some districts | No | No (school dependent) | No (school dependent) |

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Produced by

Australia: Deborah Corrigan

China: Xu Binyan and Zhu Yan

New Zealand: Beverley Cooper and Bronwen Cowie

Russia: Nikilay Konstantinov, Petr Sergeev, Ivan Vysotskiy and Ivan Yaschenko

Singapore: Wong Khoon Yoong, Tan Kok Siang, Lee Ngan Hoe and Darren Wong

Thailand: Inprasitha Maitree, Srisawasdi Niwat and Thinwiangthong Sampan

United States: Alan Ginsburg, Sherri Lauver, Rebecca Maynard, Eileen Murray and Jon Star

For

Asia-Pacific Economic Cooperation Secretariat

35 Heng Mui Keng Terrace

Singapore 119616

Tel: (65) 68919 600

Fax: (65) 68919 690

Email: info@apec.org

Website: www.apec.org

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