LEARNING FIRST

Working Paper: Teacher Subject Expertise

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The Community of Practice for improving initial teacher education

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Learning First conducted the analysis presented in this report. The interpretations of how these systems operate are the authors', and do not necessarily represent the views or official positions of governments or officials in the systems analyzed.

Learning First produced this working paper as part of the global Initial Teacher Education (ITE) Community of Practice (CoP).

This paper was written to help teams in the CoP think about how to build subject expertise in novice teachers. **This paper is a working draft and should not be cited.**

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Figure 1: What this paper is about and why it matters

What this paper is about	Why this matters to you
1. Defining teacher subject expertise.	Teacher subject expertise is poorly understood – policy interventions must be informed by a more complete understanding.
2. Explaining the problem with teacher subject expertise.	Existing explanations tend to focus on the relatively poor outcomes of teachers on tests of literacy and numeracy. While this is important, it is more important to recognize specific deficits in the specialized knowledge required for teaching.
3. Making a case for ITE being a key lever to build teacher subject expertise.	The design of teacher preparation is crucial if ITE is to be a lever to "break the cycle" of poor educational outcomes by building teacher subject expertise.
4. Measuring teacher expertise.	Measures of teacher knowledge need to be valid, and we need to be aware of poor proxies. Many systems want to measure teacher knowledge via proxies including Master's degrees, or number of content courses taken. This is poor practice.
5. Policy options to change ITE and support teacher subject expertise.	There are a number of levers available to ITE providers and policy makers – it's important to consider which ones might be right for your context .

We are learning more and more about what makes teachers effective. From general pedagogical skills, such as knowing how to control a classroom, to personal attributes such as motivation and personal beliefs about student learning, there are many factors correlated with effective teaching.[1] Knowledge of the subject, knowledge of teaching (including general pedagogical skills), knowledge of the curriculum and knowledge of learners are all types of knowledge that help to make teachers effective in the classroom.[2] This paper focuses on one of these important attributes: knowledge of the subject (or subject expertise), the idea that teachers need a strong background in the subject or subjects they teach, including factual knowledge about the subject and an understanding of how to teach it.

Inadequate teacher subject expertise impacts students across all age levels -– not just in secondary school but in elementary years as well.[3] While the concepts and skills taught in elementary school can appear straightforward, teachers know that teaching them effectively is no simple matter. In light of this, initial teacher education (ITE) providers are turning their attention towards supporting prospective teachers develop better subject expertise.

Teacher subject expertise in ITE is a difficult area of research and policymaking. As subject expertise is related to teachers' general cognitive ability and attitudes/beliefs, it is conceptually and methodologically challenging to find out how ITE programs affect subject expertise development.[4] Most research on pre-service teachers is not longitudinal, which means we have a very limited understanding of how learning in

[1] Coe, Aloisi, Higgins, & Major, 2014
[2] Allen, 2003; Coe et al., 2014; National Research Council, 2010; Shulman, 1986
[3] Campbell et al., 2014; Piasta, Connor, Fishman, & Morrison, 2009; E. A. Hanushek, 2010; Ingvarson, Beavis, Bishop, Peck, & Elsworth, 2004
[4] Gitomer & Zisk, 2015

ITE takes place and the impact any intervention has over time. Additionally, most research into pre-service teacher expertise has been in mathematics (and to a lesser extent, science and literacy). The role of teacher subject expertise in humanities, social sciences and other subjects is much less understood.

Despite these limitations, there are sound reasons to consider ITE programs as an opportunity to improve teacher subject expertise. ITE presents an extremely valuable opportunity to redress gaps in teacher knowledge and build capacity, especially given that most in-service professional learning is currently not set up to develop subject specific skills in many systems.[5]

As we learn more about what skills and knowledge makes teachers effective, we need to continue to ask ourselves how teachers can best learn these things and how ITE should be designed in order to facilitate this learning. Many teams within the CoP are piloting initiatives to support the development of teacher subject expertise, and this paper has been written to aid these efforts. After a brief discussion of why subject expertise is important, this paper will provide a short overview of the existing evidence base on what subject expertise teachers should have and how this might be measured. Lastly, it considers how ITE providers and policymakers can better develop the subject expertise of pre-service teachers.

1.1 What is subject expertise?

As with all sub-types of teacher knowledge, definitions tend to be only agreed upon at a high level and the details are left open to debate. It is generally agreed, however, that teacher subject expertise comprises both 'content knowledge' (CK) and 'pedagogical content knowledge' (PCK).

CK can be defined as an academic or technical understanding of a particular subject area, for example, knowledge of high school level geometry in mathematics. CK includes factors such as:

- Knowing facts and concepts in the subject
- Understanding the organization and structure of the discipline

PCK refers to the interaction of content knowledge and knowledge of how students learn. It includes understanding of how students learn specific content, approaches to explaining new concepts, and the ability to convey what needs to be learned. PCK includes factors such as:

- Knowing the best ways to represent ideas
- Understanding student preconceptions and partial understandings
- Anticipation of student thinking[6]

Box 1: Example of the difference between CK and PCK in elementary mathematics

An elementary mathematics teacher needs specific CK and PCK to teach fractions to a particular grade level. For example, the relevant CK might include the teacher understanding that 1½ is the same as 3/2 and how to prove that this is true. A component of the related PCK involves the teacher anticipating that her students might confuse the numerator and the denominator when converting fractions. The teacher needs both of these elements of subject expertise in order to properly support student understanding.

Though we can consider CK and PCK separately, they are related and they interact.[7] Specifically, PCK requires the interaction of content with pedagogical skill and understanding of student ability. For example,

[5] Jensen, Sonnemann, Roberts-Hull, & Hunter, 2016
[6] See, for example, Shulman, 1986
[7] Jüttner, Boone, Park, & Neuhaus, 2013

a key tenant of PCK is being able to anticipate and correct incomplete (or mistaken) student understandings. This is necessary to advance student learning and includes knowing why a student might make a particular type of mistake and knowing how to correct it.[8]

As such, both components of subject expertise are directly related to teacher effectiveness. While subject expertise is not the only necessary component of good teaching, effective teaching is limited when there is a lack of knowledge of the subject being taught. In the example above, a teacher with poor CK may not understand the facts and concepts of the subject well enough to exercise good PCK and help a student overcome her partial understanding.

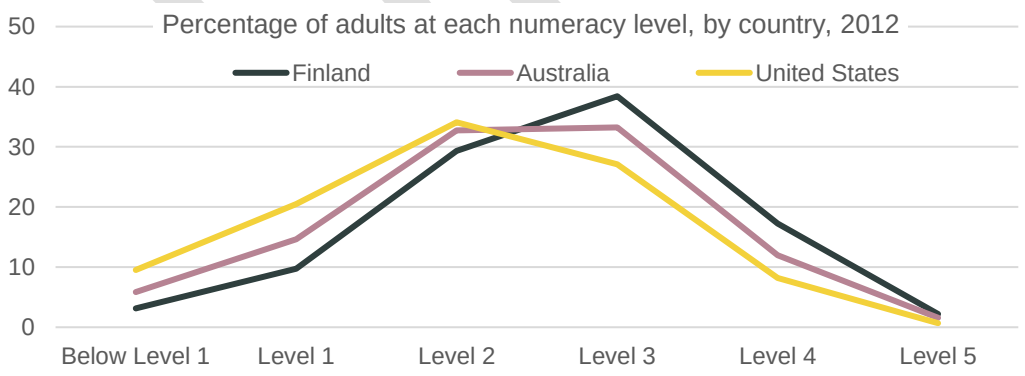
Novice teachers with low subject expertise are likely to rely heavily on textbooks and to use more basic approaches to teaching, resulting in only shallow student understanding of procedures.[9] What defines the profound understanding of expert teachers is the ability to focus on the most relevant information and to organize this in a way that aids student learning.[10] These teachers not only know what information to teach, they know how to teach it, including how to sequence and scaffold ideas to best support diverse student understandings in their classroom.

While there may be much that can only be truly learned from experience teaching students, there is a substantial body of PCK in each area of teaching that beginning teachers should be acquainted with. Emerging research on subject expertise suggests that CK and PCK can and should be developed simultaneously in ITE.[11]

1.2 The problem with teacher knowledge

Cross-country studies show that a large proportion of adults leave formal schooling with very limited numeracy and literacy skills. Figure 2 shows how three countries in the CoP performed in the Program for International Assessment of Adult Competencies (PIAAC). Only 36% of American and 47% of Australian adults attained Level 3 or above, compared to 58% of Finns.[12] At this level (previously considered the 'minimum required for individuals to meet the complex demands of everyday life and work'[13]), participants are able to do some mathematical problem solving with more than one step, conduct basic data analysis, and read statistics in tables and graphs.

Figure 2: Adult skill levels vary widely

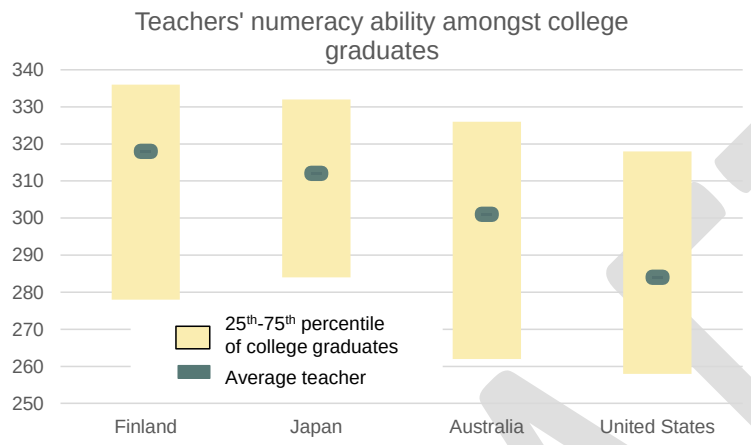


[8] In science, teachers with these skills had greater student achievement gains, see: Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013
[9] Cochran, King, & DeRuiter, 1991
[10] Hattie, 2011
[11] Ball, 2000; Darling-Hammond & Bransford, 2005
[12] Program for the International Assessment of Adult Competencies, 2012
[13] See Mendelovits, 2015

Source: PIAAC 2012.

Teachers are themselves recipients of the education systems that produce these results. Figure 3 shows the numeracy ability of the average tertiary-educated teacher against the middle half (25th-75th percentile) of college-educated adults. Across the OECD, teachers are not, on average, at the bottom of the distribution. Yet it's clear that teachers in top systems are far more skilled than in countries such as Australia and the U.S.[14]

Figure 3: Teacher and overall college graduate numeracy ability



Source: PIAAC 2012. Note: refers to all adults aged 16-64 with university qualifications from the 2013 PIAAC data.[15] Seven score points are equivalent to a year of schooling, so the difference between an American and Finnish teacher is about five years of education.

These statistics are compounded by evidence that many teachers have not mastered the content they will be teaching to students on completing ITE.[16] It is often assumed that entrants to ITE, equipped with a secondary education, arrive at university with sufficient knowledge to teach the math, science, literacy and social sciences that comprise much of the curriculum, or at least possess the skills to learn the content ahead of the students.

This is not the case, and little should be taken for granted about the existing abilities of entrants into the system. Even intelligent, college-educated adults may be missing fundamental concepts and abilities that they theoretically should have acquired in their education (see Box 2).

Box 2: Adults and teachers have been found to have low skills in science and numeracy

Even college-educated adults, including teachers, may be missing a deeper understanding of basics in science and numeracy subjects. There have been many studies documenting this gap in knowledge, including:

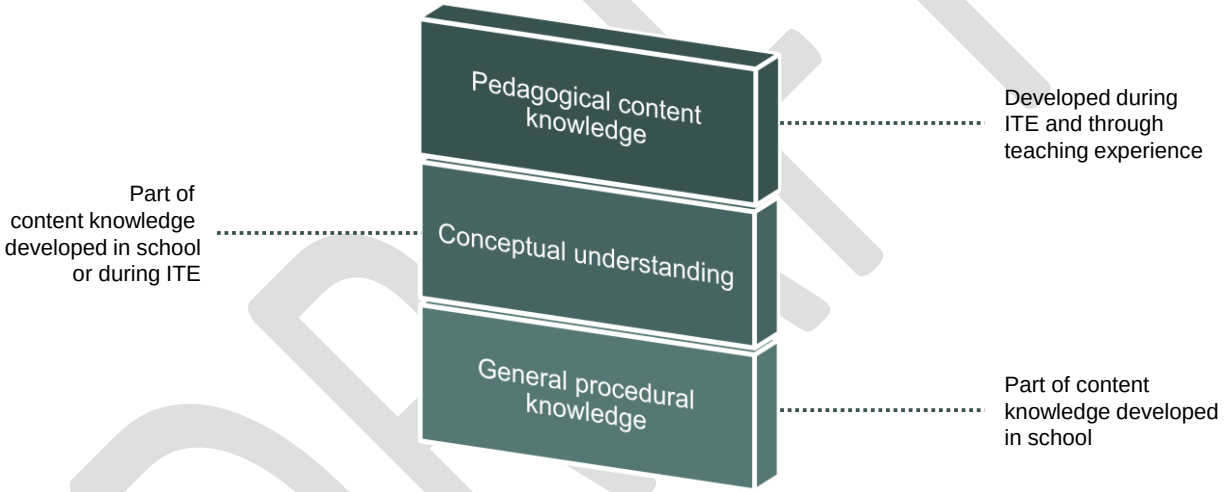
- Studies of science undergraduates and postgraduates discovered widespread incorrect understandings of evolution, such as that organisms are 'trying' to change to fit the environment.[17] Similar issues have been continually pointed out in studies of teachers.

[14] OECD, 2013
[15] Eric A. Hanushek, Piopiunik, & Wiederhold, 2014
[16] Ma, 1999
[17] Gregory, 2009; Gregory & Ellis, 2009

- In an Australian study, only 50% of in-service teachers could correctly order the numbers 3.03, 3.033, 3.303 and 3.33 from lowest to highest (content taught to ten-year-olds), while 25% of pre-service teachers who had just completed a math course could not correctly answer this question.[18]
- In a study of in-service elementary science teachers in Ohio, more than a third indicated that gases are lighter than solids and liquids, and 43% appeared to believe that some substances are inherently colder than others (e.g. that wool will be 'warmer' than glass when both are at room temperature).[19]

It's also important to recognize that CK is not just general knowledge of the kind that all adults are expected to have – it is specialized for teaching. Even adults who have good numeracy knowledge, for example, most likely wouldn't have the CK required to teach an elementary mathematics class. There is a distinction between general procedural knowledge, such as knowing the steps to take to invert and multiply two fractions together, and conceptual understanding – actually understanding why this process works. Many adults will possess a procedural understanding of the multiplication of fractions, but few would possess a true conceptual understanding. PCK is different again, and typically only held by people who have undertaken ITE. Figure 4 below outlines where we might expect each type of knowledge to be developed.

Figure 4: Components of CK and PCK and where they are developed during the education of prospective teachers



Some may find it difficult to believe that seemingly rudimentary mathematical concepts like two-digit subtraction with regrouping, for example, are especially difficult to teach. Many teachers would be surprised to find, however, that their procedural approach to this topic with elementary-aged children leads to limitations in children's understandings that may persist throughout their lives.[20] For example, it would not be uncommon in many countries for a teacher to teach subtraction with regrouping using an example such as 67-49, by explaining to students: 'you can't take a bigger number (9) away from a small number (7), so you have to borrow a 1 from the 7's next door neighbor, and then subtract 9 from 17 before completing the rest of the equation'.[21]

While this approach may lead students to an answer that is technically correct, it is conceptually problematic in a number of ways. 49 is not a 'bigger number' than 67, and students will later learn that they *can* subtract a 'bigger number' from a 'smaller number'. It is also problematic to talk about 'borrowing' during a lesson on two-digit subtraction with regrouping – students may wonder when they need to return

[18] Muir & Livy, 2012 Maher & Muir, 2011
[19] Burgoon, Heddle, & Duran, 2010
[20] Ma, 1999
[21] A seminal study by Liping Ma found that a majority of U.S. elementary teachers surveyd approached subtraction with regrouping in this way. See Ma, 1999

what they have borrowed. It is also incorrect to treat the 6 tens and 7 ones that make up the number 67 as 'next-door neighbors' when they are part of the same number. Teachers with poor PCK may attempt to use manipulatives (such as marbles) to demonstrate this concept to children, but may not recognize that this approach does not demonstrate the concept of regrouping. This very common procedural approach to two-digit subtraction with regrouping has serious, lasting implications for students' understanding of fundamental numeracy concepts.

Teachers with strong subject expertise would take a different approach to this topic. These teachers might ask students whether it is possible to subtract a number in the 40s from a number in the 60s. When students agree that it is possible, these teachers may ask students to attempt to solve the problem using bundled popsicle sticks to demonstrate equivalent groupings of ten and scattered ones, before leading a class discussion to determine the most effective strategies to complete the equation. Teachers with strong subject expertise would also seek to connect students' understanding of two-digit subtraction with regrouping to related concepts taught previously, such as addition with carrying. This conceptual approach to a seemingly easy mathematical concept gives students a much stronger base to further their mathematical understanding throughout their schooling and beyond.[22]

1.3 Why must ITE be part of the solution?

It is clear that ITE institutions across all systems grapple with pre-service teacher candidates with a varying range of abilities and CK. Calls to raise the caliber of entrants into ITE can be worthwhile, especially where they seek to raise the status of the profession more generally, but simply having higher-quality entrants *into* ITE does not address the issue of what happens *in* tertiary education and teacher training. Systems need to meet prospective teachers where they are at and ensure they leave ITE with a level of CK and PCK appropriate to their future teaching assignments.

ITE is not the only opportunity to develop this knowledge in teachers, but it is an important threshold where systems can intervene and ensure that prospective teachers have adequate subject expertise.[23] For systems with low barriers to ITE selection, ITE could be a point to 'break the cycle' of poor educational outcomes generating poor educational outcomes. For many teachers, their ITE may be one of the few opportunities in their career where they have the time, support and resources to learn content in a comprehensive way.

The content of ITE itself can have a substantial impact on what beginning teachers know and can do. Well-designed ITE programs can help prospective teachers confront false beliefs about content and build correct ones. Given that entrants to ITE are unlikely to have the PCK and skills (whatever their CK), it is also an opportunity to lay the first groundwork of PCK. Laying this PCK groundwork can also act as a course in remedial CK at the level teachers will need to understand in order to adequately support the learning of their students. Great ITE can give teachers the skills to continue learning over their careers and developing mastery in the subjects they teach.

1.4 What do teachers need to know?

The strongest empirical evidence reinforces the idea that teachers should have a deep understanding of at least the content they are teaching.[24] However, this means so much more than just understanding the content as it is written in the curriculum or in the textbook. Teachers require a 'profound understanding' of the content they are teaching, which means they need to understand the material they are teaching in-

[22] This example has been adapted from Ma, 1999
[23] Ward, Grudnoff, Brooker, & Simpson, 2013
[24] Allen, 2003; Coe et al., 2014; National Research Council, 2010

depth, accurately and without confusion.[25] There is evidence to suggest that elementary school teachers are better off becoming experts in the foundational content taught in the lower grades, rather than studying advanced content.[26]

Sometimes it seems like changes in the school curriculum, the learning and developmental level of students, and advances in the field make it difficult to define what the 'right' content knowledge is for any teacher. However, ensuring that ITE is aligned to the school curriculum – so that topics in the elementary school curriculum are covered in elementary ITE, and topics in the secondary school curriculum are covered in secondary ITE – is a good place to start. It has been very difficult to do this in nations without a central curriculum such as the U.S., particularly prior to the introduction of the Common Core State Standards. The need for alignment highlights the importance of schools and districts working together, particularly in situations where there is not a detailed and comprehensive common curriculum. While preparing teachers with more advanced knowledge might be useful, in the time-constrained context of ITE it is important to focus on curriculum-aligned content first. Ideally it appears that teacher knowledge should go beyond simply what students need to know at any given point in time and consist of a coherent, flexible understanding that is able to adapt to changes in curricula and changes in the student cohort.

Professional associations and education researchers have frequently made recommendations about what teachers should know to teach different grade levels and content areas, and therefore what ITE programs should ensure pre-service teachers know.[27] We have included a few examples of recommended CK and PCK for mathematics, literacy and science here. These are not intended to be prescriptive or exhaustive, rather they include some of the current available guidelines of best practice. It is also worth noting that the majority of the recent research conducted by Learning First has centered around elementary education, so many of our examples, especially related to math and literacy, focus more on the elementary level.

1.4.1 Mathematics

For elementary mathematics, a focus on numbers and operations, algebra and geometry/measurement, with a little data analysis and probability, should be at the core of teacher preparation.[28] From a CK perspective, a focus on these areas enables teachers to understand these topics to a level where they can explain *why* a certain thing is so. This means having an understanding of the underlying mathematics, rather than simply being able to give examples of how to complete certain problems.[29]

From a PCK perspective, teachers need to understand how best to support student learning of these topics, including how to choose examples and activities that best illuminate the mathematical concepts, and how to identify when students have an incomplete understanding of a particular topic. For example, teachers need to know how to identify when a student is relying on procedural knowledge to generate a correct answer in a problem involving the multiplication of fractions – many students may simply learn to 'invert and multiply' rather than developing a sound mathematical understanding of the topic.[30] While this may not seem like a significant problem if a student is achieving the correct answer, incomplete understandings can (and do) have significant implications for the development of students' further mathematical knowledge.

[25] Ma, 1999
[26] See, for example, Ball, Thames, & Phelps, 2008
[27] National Research Council, 2010 is perhaps the widest review of this body of knowledge in math, science and reading.
[28] Greenberg & Walsh, 2008
[29] Tchoshanov, 2010
[30] Ball, 1988; Olanoff et al., 2014

1.4.2 Literacy

The subject expertise required for good literacy instruction is often overlooked – we assume that all teachers know how to read, and that should be enough to know how to teach students how to read. However, teachers require a wide range of technical subject expertise in order to adequately support student learning. The relevant CK for literacy includes language comprehension, itself requiring a knowledge of things like vocabulary, morphology, genre and reading fluency; and word analysis, including things like phonemic awareness, letter sound relationships, and the ability to decode unfamiliar words.[31]

PCK for literacy builds on teachers' CK and requires knowledge of the process of learning to read, difficulties students may encounter, and research on the effectiveness of various pedagogical strategies. The U.S.-based National Reading Panel (2000) recommended that teachers be knowledgeable about a number of approaches to reading instruction, including: systemic teaching of phonemic awareness, explicit phonics instruction, guided oral reading to improve fluency, teaching vocabulary words and comprehension.[32]

Apart from instructional specifics, literacy is important for teachers of all subjects and all year levels. Teachers need to model correct use of language, produce notes and content that is clear, correct student work and give meaningful feedback, and select appropriate metaphors and examples to aid student learning – all of which requires higher-level literacy.[33] Each subject area has its own language and specific literacy that teachers need to be well-versed in to properly support student learning.

1.4.3 Science

While CK for secondary science tends to branch out into discrete specializations such as biology, chemistry and physics, CK for elementary level science is broader. At the lower year levels, students tend to be introduced to scientific reasoning (such as experimentation and the scientific method), patterns, cause and effect, and stability and change. Topics including organisms, planets and energy are also typically covered.[34]

As with other subjects, PCK for science includes the ability to understand and confront student preconceptions or partial understandings. Partial understandings are common in the sciences – many people make it to adulthood with incorrect understandings about seasonal change, or how gravity works. Science teachers need to know how to design or select activities and resources that create cognitive conflict and help students confront these misconceptions.[35] Science teachers also need to know how enact inquiry-based pedagogies in a way that supports student learning and is strongly connected to the content being taught. While inquiry-based learning is prominent in the sciences, it can be easily misused and disconnected from learning if teachers have weak PCK.

[31] Phelps & Schilling, 2004(Snow, Griffin, and Burns 2005)
[32] National Institute of Child Health and Human Development, 2000
[33] Moon, 2014
[34] Next Generation Science Standards, 2015 National Academies Press, 2012
[35] Gomez-Zwiep, 2008; Lucariello & Naff, n.d.

Table 1: Sample of recommended content knowledge for teachers in science for one content area[36]

Core subject area	Elementary content knowledge	High school content knowledge
Science (earth and space science)	• Differences between renewable and non-renewable energy • Basic properties of rocks, minerals, water, air and energy • Causes of the seasons • Changes in atmosphere creating weather and climate • The history of Earth and place in the solar system	• Geochemical cycles • Land formation and erosion • Energy flow and transformation in Earth systems • Patterns in weather and climate • Sources and limits of natural resources • Processes used for investigation in the earth and space sciences • Origin and properties of the universe

1.5 How do we measure teacher knowledge?

Reliable measures of teacher subject expertise can help improve student outcomes by identifying learning needs and gaps in teacher knowledge at every stage of the teacher education pathway.[37] The teacher education pathway (Figure 5) depicts the different stages of beginning teachers' education, from selection into ITE through to their first years of teaching. In general, the reforms at the beginning of the pathway impact prospective teachers, while reforms later in the pathway impact both potential teachers and ITE providers.[38]

Figure 5: Teacher education pathway

High-performing systems internationally assess teacher knowledge in a number of different ways at different points along this pathway. For example, prospective teachers in Finland take a centralized examination as part of the ITE selection process which involves a series of multiple-choice questions based on academic material published approximately six weeks before the exam. The material and examination is highly challenging and covers a range of pedagogically relevant topics.[39]

Box 3: Sample questions from Finnish ITE selection examination

The below question relates to an academic article that prospective Finnish teachers were expected to have studied prior to sitting the exam.[40] The article describes a variety of path dependences and objectives connected to the early childhood education system. Candidates were asked to connect the individual objectives to the path dependencies mentioned in the article.

Path dependencies:

1. Social democratic path dependence
2. Liberal path dependence

[36] National Science Teachers Association, 2012
[37] Coe et al., 2014
[38] Roberts-Hull, Jensen, & Cooper, 2015
[39] Please refer to the VAKAVA assessment in your personalized playlist
[40] For a list of the Finnish articles candidates were expected to study prior to the 2015 exam, please refer to: http://www.helsinki.fi/vakava/lista%20artikkeleista.pdf

3. Child-oriented path dependence

Objectives:

A. Getting to know arts and culture should be part of the early childhood education
B. It is important that teachers' sufficient freedom on choosing the content of their teaching is secured by legislation
C. In order to guarantee parents freedom of choice in early childhood education, service vouchers should be introduced.
D. Observing gender sensitivity in the contents of early childhood education
E. Children's rights are a key starting point in early childhood education
F. Minority group children's rights to their own cultural heritage should be supported
G. Children should have the right to free day care
H. Every child needs skills for encountering families' diversities
I. Foster care's like day care's objective is to enable parents paid employment
J. Economic aspects related to early childhood education should not be forgotten

Excerpt translated from the original Finnish.[41] Full English version available in your personalized playlist.

Conversely, Japan chooses to assess teacher knowledge at the point of hiring. Prospective Japanese teachers must pass one or more employment exams set by the prefectural board of education they are seeking employment with. These exams can include demonstration lessons, interviews and written examinations. The candidates that perform best in these assessments are successful in gaining employment with the prefecture.

Box 4: Sample question from a Japanese prefectural written employment exam

There is a rectangle ABCD and a square EFGH. The length of the edge AD in the rectangle is twice as long as the edge AB. Also, each edge of the square is 3 cm longer than the length of the edge AB in the rectangle, and the mass is smaller than that of rectangle for 7cm^2. Choose one of the next 1-4 as the right length of the edge AB in the rectangle.

1. 2cm
2. 4cm
3. 6cm
4. 8cm

Questions is from the 2015 elementary teacher employment exam in Saitama prefecture.[42]

1.5.1 Beware of proxy measures of CK

Generally speaking, direct measures of teacher knowledge are more relevant to student achievement than 'proxy' measures such as degree type.[43] There have been many attempts to measure how teacher qualifications, number of ITE courses taken, and other measures affect student learning, and there is no good evidence that any of these 'proxy' measures lead to better results for students.[44] For example, a study by Diamond, Maerten-Rivera and Rohrer (2013) found that science teacher test scores and scores

[41] "VAKAVA exam - Questions and correct answers," 2015
[42] Saitama Prefectural Board of Education, 2015
[43] See Allen, 2003; Hill, Ball, & Rowan, 2005; Kilpatrick, Swafford, & Findell, 2001; Tretter, Brown, Bush, Saderholm, & Holmes, 2013; S. Wilson & Floden, 2003; S. M. Wilson, Floden, & Ferrini-Mundy, 2002.
[44] Allen, 2003; National Research Council, 2010.

based on observations of their practice were not correlated with the number of science courses teachers had taken, though they were correlated with each other.[45]

The evidence suggests having an undergraduate major or even a degree in a subject area may be of limited use in a classroom, as the material taught is often quite different.[46] This is particularly relevant to secondary school teachers, who may not enter ITE with relevant knowledge of the material they are expected to teach, even if they have knowledge in a related area. Some studies find that there are positive correlations with having a major in certain subject areas and student achievement, but the evidence is mixed.[47]

Another poor proxy for teacher knowledge is counting the number of courses teachers have taken in a particular subject area. Similar to K-12 education, the quality of university courses are highly reliant on the quality of the teacher educator. For this reason, just noting the fact that a teacher completed a course tells one little about how much the teacher learned in the course. Courses with the same name can be highly variable, so a focus on learning outcomes from courses is often more useful than just counting courses taken.[48]

Master's degrees are also a poor proxy for teacher subject expertise. In many U.S. states, there is an incentive for teachers to obtain Master's degrees as higher qualifications lead to a certain increase in salary.[49] This has led to many teachers simply choosing the most convenient Master's program, rather than choosing based on quality or content. Perhaps as a result, teachers with Master's degrees are not predictably more effective than those without them.[50] Even Master's degrees that *are* content-related are unlikely to lead to better student outcomes unless they are specifically related to how better to teach this content to students.[51]

Policies attempting to raise teacher subject expertise through requiring more courses or higher degrees are unlikely to succeed unless careful attention is also paid to the specifics of subject matter coursework and the learning outcomes of teacher candidates in ITE.

1.5.2 How can we measure teacher knowledge in ITE?

In the U.S., tests of CK and PCK such as the ETS Praxis exams and Pearson's National Evaluation Series are widely used.[52] However, as Coe *et al* note in their review of effective teaching, many of the measures we currently have of teacher effectiveness are not by themselves adequate for high-stakes decision making as the link between what they measure and what is needed for teaching is not proven.[53] Clearly, such tests should measure skills that classroom teachers actually need.

More formative assessments of teacher knowledge are better-researched. Tools such as knowledge maps have been shown to help prospective student teachers understand how the knowledge they are building relates to other areas and allows them to understand what content areas they need to work on.[54] Assessments using video footage have been shown to be effective in improving teaching and could be

[45] Diamond, Maerten-Rivera, & Rohrer, 2013
[46] Aaronson, Barrow, & Sander, 2007; Tatto et al., 2012.
[47] Harris & Sass, 2007
[48] Allen, 2003
[49] Chingos, 2014
[50] E.A. Hanushek, 2003; Eric A. Hanushek, 2002; Leigh, 2010; Rivkin, Hanushek, & Kain, 2005
[51] Clotfelter, Ladd, & Vigdor, 2007
[52] Louden, 2015
[53] Coe et al., 2014; Kirchner, 2012; Thanheiser, Browning, Edson, Kastberg, & Lo, 2013
[54] Poling, Goodson-Espy, Dean, Lynch-Davis, & Quickenton, n.d.

used much more widely in ITE.[55] Box 5 gives one example of how formative assessment is tied to required content in ITE.

Box 5: TeachingWorks

The TeachingWorks program at the University of Michigan has attempted to reform ITE curriculum based on its research program of what constitutes effective teaching. This research has identified 'high-leverage content' – the specific things most useful for teachers to learn in ITE – and 'high-leverage practices' in the classroom that enhance student learning in specific content areas.

In mathematics, for example, TeachingWorks has identified number and operations, fractions, and place value as 'high leverage content' for teachers. In literacy, fundamental grammar, persuasive writing and literary themes are deemed high-leverage.

High-leverage practices are taught alongside content to ensure prospective teachers are able to integrate the two. Teacher candidate progress is assessed through a range of techniques including classroom observation, extended-response tests, and one-on-one coaching sessions.[56]

One particularly promising form of assessment of subject expertise is the use of multiple choice tests with additional questions for open-ended explanation of how test-takers arrived at the answer.[57] Similarly, tests for common student misconceptions can also be useful.[58] Subject expertise should be assessed and feedback given in practical settings, too. For instance, in one assessment used by the TeachingWorks program, pre-service teachers' subject expertise is evaluated partly based on how well they can elicit and interpret student thinking in a class discussion.[59] Other ITE providers have been experimenting with micro-credentialing of content and pedagogical content.[60]

Reliable measures of CK are still being developed. The best approach for systems to take will depend on how their ITE programs are designed, what they do with assessments of teacher knowledge, and the subject expertise they require of pre-service teachers.

[55] Hattie, 2009
[56] Davis & Boerst, 2014
[57] Phelps, Weren, Croft, & Gitomer, 2014
[58] Hill, 2010; Hill et al., 2005; Hill, Schilling, & Ball, 2004
[59] Davis & Boerst, 2014
[60] Cator, Schneider, & Vander Ark, 2014

2 How to change ITE

What constitutes good design of ITE courses is a heavily contested area. In the U.S., there have been mixed results when attempting to determine the quality of ITE providers based on student outcomes.[61]

Some courses appear to routinely produce more effective teachers, but the effects are small and the underlying reasons *why* a program is more successful than others are still unclear.[62] A focus in ITE on the skills and knowledge required by beginning teachers may lead to better-prepared graduates, though there are few studies differentiating between the classroom impacts of different instructional methods in ITE.[63]

Tapping into prospective teachers' prior knowledge and changing the ITE curriculum to foster a deeper understanding of the subjects and year levels being taught are two instructional options for ITE providers that are underpinned by promising emerging research. Broader options that may also include government and policymakers include reforming policies around evaluation, funding and dialogue, and utilizing other levers along the teacher education pathway.

2.1.1 Use of prior knowledge

Prior knowledge plays a crucial role in learning for students and teachers alike.[64] Courses in ITE need to engage the initial understanding of entrants into ITE in order to build subject expertise. It should be expected that prospective teachers have mixed abilities, and some will have misconceptions about the content areas they are studying – this is particularly the case in school systems that are weaker and have low barriers of entry into ITE programs.[65] However, while ITE programs might instruct prospective teachers to check what students already know and use this knowledge as a way 'into' learning, the prior knowledge of students in ITE is rarely considered.

Systems seeking to improve the subject expertise of their teachers could consider undertaking an assessment of the skills and knowledge of entrants. This information could be shared with teacher educators and used to better inform course design while also helping candidates to identify their own learning needs.[66] Instruction could be geared in a way that best addresses the needs of the group and could also be individualized. For example, if there is an identified gap in CK, students might be assigned additional readings on the topic to complete in their own time.

Delivering CK to prospective teachers during ITE is a valuable opportunity to develop their PCK. When pre-service teachers in ITE are revisiting content taught to students, they have an opportunity to learn why certain ideas are hard to grasp, how to select appropriate examples to aid student learning, and to understand the pitfalls of using certain techniques. This approach not only helps prospective teachers develop a deeper understanding of the subject they are teaching – it also shows them how to teach it in a way that is useful for student learning.

The use of prior knowledge (and learning progress in ITE) has been recognized by some ITE providers who are moving to a micro-credentialing model. 'Competency-based' progression through ITE has the

[61] Sherman & Ding, 2008; Sleeter, 2014; Wiens, 2012
[62] Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Goldhaber, Liddle, & Theobald, 2013; Bastian, Patterson, & Pan, 2015
[63] Boyd et al., 2009
[64] Bransford, Brown, Cocking, & others, 2000
[65] (Áine, Childs, & Hayes, 2011; Atwood & Christopher, 2006; Gregory & Ellis, 2009; Ryan & McCrae, 2005; Murphy & Smith, 2012)).
[66] Toh, Kaur, & Koay, 2013

potential to better align ITE to teacher professional development and ensure specific issues with subject expertise are picked up and addressed.[67]

2.2 Deeper knowledge through good curriculum design

All ITE providers grapple with time constraints to varying degrees and must consider how best to structure courses to help teachers achieve a profound understanding of the subjects they will teach. So, how can we structure ITE to achieve profound understanding? One possibility that is sometimes considered is to increase the length of ITE or get teachers to do more courses. However, this is very expensive and not very effective. Instead, we need to restructure ITE, making trade-offs to prioritize the development of profound understanding. An increased focus on subject expertise will involve trade-offs against other topics. In Singapore for instance, elective courses – such as the history and theory of education and curriculum and assessment design – were removed from ITE to make way for more subject expertise development and practicums.[68]

Given their limited time, ITE programs should not attempt to cover every possible topic that might be on a curriculum if it means sacrificing depth and competence in foundational skills. Successive reports have made the case for a simplified ITE curriculum that does a few things well; where instruction consists largely of developing a profound understanding of the content that teachers will eventually teach, that is well-integrated with pedagogical practice, and where subject experts work closely with the education faculty.[69] The recommendations for ITE curricula across science, reading and literacy are remarkably similar.

Subject expertise should be integrated into the daily practice of teaching – there need not be a distinction between the content and pedagogy in ITE. Some promising practices to situate content in practical settings during ITE include videotaped lesson analysis, using student work to analyze learning and understanding, and lesson observation and coaching with more experienced teachers. Further considerations include the composition and experience of the faculty, including whether subject specialists or pedagogy specialists are best placed to teach particular units. In systems such as Finland, ITE lecturers possess both a subject specialty and advanced pedagogical training.

Box 6: Aligning ITE programs to new standards

The introduction of the Common Core State Standards in the U.S. presents challenges for school systems and ITE providers alike. The shift to the standards, which are designed to be narrower and deeper across subjects, requires that teachers themselves have a deeper level of knowledge.

Significant work has been done on what Common Core-ready teachers need to do in the classroom, and how ITE can prepare pre-service teachers with the ability to help students meet the standards.[70] ITE providers will need to assess what is taught to prospective teachers and evaluate whether they are preparing teachers able to help students meet the standards. They may also need to refigure content to reflect the higher expectations of learning in both elementary and secondary years.

For instance, an ongoing collaborative research project in secondary mathematics teacher education has developed guiding principles for ITE program design, including guidelines for both subject expertise and pedagogical skill development. It also suggests guidelines for differentiated instructional strategies and assessment.[71]

[67] Council of Chief State School Officers, 2013
[68] Jensen, Hunter, Sonnemann, & Burns, 2012
[69] For instance see Bransford et al., 2000; Conference Board of the Mathematical Sciences, 2010; National Research Council, 2010; Paliokas, 2014
[70] See Achieve & US Education Delivery Institute, 2012; "Common Core State Standards Resources," n.d., "Teaching the Core," n.d.; Conference Board of the Mathematical Sciences, 2010; Litt, Martin, & Place, 2014
[71] Mathematics Teacher Education Partnership, 2014

2.3 Broader options to support subject matter knowledge development in ITE

There are a number of broader options to influence ITE programs. These options can involve governments, policymakers, and ITE providers in varying combinations. In some systems, governments have a very high degree of control over the higher education sector. In these systems it may be relatively straightforward to pass requirements for certain types of content to be included in ITE. In these situations, ITE providers have no choice but to comply with government requirements.

In systems where governments have less control over higher education, they may attempt to influence the subject expertise of teachers by targeting other parts of the teacher development pathway. For example, they may choose to set stricter or more specific requirements at the teacher certification or hiring stages of the development pathway, effectively pushing ITE providers to change their curriculum so their candidates are adequately prepared to clear these hurdles.

A greater focus on subject expertise can also be facilitated through the ITE evaluation process. A focus on subject expertise in ITE evaluation incentivizes ITE providers to adapt their courses, especially in systems where there are meaningful consequences attached to the evaluative process. Including teacher educators in this focus may also make sense. Teacher educators, like teachers themselves, need professional learning to improve their teaching and to improve their subject expertise. Evaluations should focus on subject expertise and should track student learning just as schools track student learning – so it is clear whether and how much prospective teachers are learning during their training.

ITE reform can also occur through funding reform. ITE receives significant public funding in most instances, and governments and policymakers can tie funding to the quality of programs or to targeted areas of strategic development.[72] Where increasing subject expertise is a priority, governments may decide to link it to ITE funding by requiring that ITE providers demonstrate adherence to a particular standard or by providing small seed grants for innovations in this area.

In smaller systems with relatively few ITE providers, regular and meaningful dialogue between providers and government can also facilitate reform. This can be a relatively cost effective way for providers to share ideas with each other and for government to give input into ITE design. While this approach has the benefit of avoiding heavy-handed regulation, it may not be successful in contexts where there are many ITE providers or where there is a great deal of competition between ITE providers.

2.4 A range of policy levers to enhance teacher subject expertise

This paper has focused on the role of ITE as a key lever to enhance teacher subject expertise, and has also briefly touched on a few other levers. These other levers can be loosely described as selection, specialization and in-school professional development. Systems may choose to select a few or all of these levers and align them to their ITE reforms in pursuit of enhanced teacher subject expertise.

The Finnish ITE entry exam and the Japanese employment exam profiled as part of this paper are examples of selection measures. Systems and programs may seek to introduce similar selection measures either before or after ITE. Selection measures implemented prior to ITE entry may focus on the capacity of applicants to understand relevant literature and apply this understanding, as with the Finnish selection example. Selection measures implemented after ITE completion may test the subject expertise of teacher through written or practical demonstrations, as the Japanese prefectural employment exams do.

[72] Roberts-Hull et al., 2015

Policies of subject specialization help create time for teachers to focus on developing subject expertise in one or two subjects, rather than all subjects. This is particularly relevant for elementary school teachers, who are often required to teach all subjects. Systems may support this by requiring all ITE providers to equip prospective teachers with a specialization. This reform is currently being considered and implemented in the Australian context by the Australian Institute of Teaching and School Leadership.[73] Schools may also consider timetabling and staffing changes that allow for specialization.

Finally, in-school professional development can also be designed and implemented to support teacher subject expertise. Partnerships between ITE providers and schools are particularly important here, as schools have the opportunity to extend and support the instruction their teachers have received during ITE. Indeed, alignment of each of these levers – selection, specialization, ITE and in-school professional development – will support the development of teacher subject expertise.

[73] Australian Institute of Teaching and School Leadership, 2014

3 Conclusion and discussion questions

3.1 Conclusion

There is increasing evidence that subject expertise is important to support teacher quality and, in turn, student learning. ITE providers have an important role in developing the subject expertise of prospective teachers, especially in places where these teachers are themselves the product of relatively weak education systems. CK and PCK are complex, even at the lowest levels of elementary schooling. ITE providers must recognize this – they might need to create space to focus on them in the ITE curriculum by considering trade-offs against other subjects and by only teaching CK through a PCK lens, and they will need to devise a curriculum that meets teacher candidates at their level. ITE providers, alongside government and policymakers, are vital in this reform process.

3.2 Questions for discussion

- Is there anything holding ITE providers back from providing more rigorous subject expertise instruction?
- What models for high-quality PCK development seem promising?
- How can prior knowledge be utilized in the design of courses for heterogeneous teacher candidate cohorts?
- Given the methodological issues with measures of candidate subject expertise, how should systems assess and set standards for teacher knowledge?
- How have different ITE programs experimented with competency-based assessments of teacher knowledge and micro-credentialing?
- What should the pathway for continued subject expertise development look like beyond ITE?
- What is the role for subject faculty (e.g. mathematics and linguistics scholars and departments) in teacher training?
- How can teacher educators stay up to date on changes to the school curriculum and standards?
- In the U.S., how should ITE providers better prepare teachers for the Common Core State Standards?

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