CHAPTER 3

TIMSS 2015 Context Questionnaire Framework

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In today's technologically-centered society, understanding how to improve student learning in mathematics and science is vital for educational policy makers, as well as principals, teachers, and parents. A strong foundation in mathematics and science is crucial for student's academic and professional development, and fundamental to the prosperity and welfare of the global community.

The TIMSS 2015 Context Questionnaire Framework establishes the foundation for the background information collected in TIMSS 2015. Through the *TIMSS 2015 Encyclopedia* and context questionnaires, TIMSS collects data about how educational systems throughout the world deliver and promote learning in mathematics and science. These data on system structure, school organization, curricula, teacher education, and classroom practices reveal many pathways to teaching and learning. In particular, when compared across countries and in relation to student achievement, this information can provide insight into effective educational strategies for development and improvement.

Participating countries each contribute a chapter to the *TIMSS 2015 Encyclopedia* and complete questionnaires to provide important information about their national policies and curricula for teaching and learning mathematics and science.

Students in the fourth or eighth year of schooling typically have gained most of their mathematics and science learning at school and at home, influenced to some extent by experiences outside of school. Community, school, classroom, and home environments that support each other can create extremely effective climates for learning. To reflect this situation, the TIMSS 2015 Context Questionnaire Framework encompasses five broad areas:

- National and community contexts;
- Home contexts;
- School contexts;
- Classroom contexts; and
- Student characteristics and attitudes toward learning.

The context questionnaires that accompany the mathematics and science assessments are an essential component of TIMSS data collection. The students as well as their parents, teachers, and school principals complete questionnaires covering a wide array of policy relevant information about the country's home and school contexts for teaching and learning mathematics and science. The student questionnaires also ask about attitudes toward learning mathematics and science.

National and Community Contexts

Cultural, social, political, and economic factors all contribute to the backdrop of student learning. At the national and community level, key educational policy decisions are made about how to best implement the curriculum, given these contextual factors. The success a country has in providing effective mathematics and science instruction depends on a number of interrelated national characteristics and decisions:

- Economic resources, population demographics, and geographic characteristics;
- Organization and structure of the educational system;
- Student flow;
- Language(s) of instruction;
- Intended mathematics and science curriculum;
- Teachers and teacher education; and
- Monitoring curriculum implementation.

Economic Resources, Population Demographics, and Geographic Characteristics

A country's economic resources, demographic characteristics, and geographic characteristics can have a tremendous impact on the relative ease or difficulty of implementing a uniformly rigorous curriculum.

- **Economic Resources**—Countries have different levels of wealth and vary in how that wealth is distributed. At the national level, economic resources and socioeconomic equity tend to be linked to favorable contexts for fostering student achievement (Chiu & Khoo, 2005). Having economic resources enables better educational facilities and a greater number of well-trained teachers and administrators. Financial resources also provide the opportunity to invest in education through widespread community programs and by making materials and technology more readily available in classrooms.
- **Population Demographics**—The size and diversity of a country's population can increase the challenges involved in curriculum implementation. Some countries have a diversity of ethnic groups, cultures, and languages, and immigration can add to the diversity of the population. The curriculum and the educational system must be flexible enough to foster student achievement for this heterogeneous population.
- **Geographic Characteristics**—The sheer size of a country can pose challenges to curriculum implementation. This is especially true if part of the population is isolated in remote parts of the country.

Organization and Structure of the Educational System

Some countries have highly centralized educational systems in which most policy-related decisions are made at the national or regional level. In these systems, often there is a great deal of educational uniformity in terms of curriculum, textbooks, and general policies. Other countries have more decentralized systems in which many important decisions are left to local governments and schools. This decentralized structure results in greater variation in how schools operate and how students are taught. Research has found that the level of centralization of standardized assessments tends to be associated with greater educational equality (Van de Werfhorst & Mijs, 2010) and higher student outcomes (Bishop & Wößmann, 2004; Jürges, Schneider, & Büchel, 2005).

Student Flow

Student flow refers to how students in an educational system progress through school. For TIMSS 2015, the student flow themes that are highly relevant include age of entry, pre-primary education, the prevalence of grade retention, and educational tracking and streaming.

- **Age of Entry—**The age of entry to formal education is particularly important for understanding achievement at the fourth grade. Due to the complexity of the cognitive demands, students in countries that begin formal schooling at a younger age do not necessarily receive much formal instruction in mathematics, and particularly in science, in their first year of schooling, whereas students starting school at a somewhat older age may receive formal instruction immediately.

- **Preprimary Education—**Even before they begin formal primary school, children may receive considerable exposure to literacy, numeracy, and science activities as part of their pre-primary educational experience. As described in the *TIMSS 2011 Encyclopedia* (Mullis, Martin, Minnich, Stanco, Centurino, & Castle, 2012), countries vary dramatically in their policies and practices with regard to early (pre-primary) education. TIMSS 2011 supported research findings that pre-primary school can have a positive effect on academic achievement during primary school (Berlinski, Galiani, & Gertler, 2009; Tucker-Drob, 2012), with longer duration of pre-primary education associated with higher achievement (Sammons et al., 2002).

- **Grade Retention—**Grade retention practices differ among countries. This variation has been explained as an effect of differing educational policies, cultural norms, and diverging perspectives on the advantages of holding students back (Goos et al., 2013). Because TIMSS is a grade-based study, the degree of grade retention can be an important factor to consider when evaluating achievement results. Research has shown that grade retention does not have a positive relationship with student achievement or the emotional wellbeing of the child (Hattie, 2009; Jimerson, 2001).

- **Tracking—**Some educational systems promote policies that steer schools to group students by ability level so that students can learn at a pace that reflects their skills in the subject. Other systems recommend tracking students at an early age by assigning students to different schools that provide academic or vocational routes. Studies on within-school tracking or ability grouping have produced mixed results (OECD, 2010; Schoffield, 2010), although studies have shown that ability grouping can be beneficial for high achieving students (Schoffield, 2010), as can offering accelerated programs to high-achievers (Steenbergen-Hu & Moon, 2011). A breadth of literature has suggested that early educational between-school tracking can exacerbate differences in student achievement (Hanushek & Wößmann, 2006; Marks, 2005; Schütz, Ursprung, & Wößmann, 2008; Van de Werfhorst & Mijs, 2010). Both within-school tracking and between-school tracking also can influence student self-concept (Chmielewski, Dumont, & Trautwein, in press), an important predictor of student achievement. The timing of the tracking is especially relevant to analyzing TIMSS' eighth grade results.

Language(s) of Instruction

A multilingual population can increase the challenge of the implementation of advanced mathematics and science curricula. TIMSS and other studies have consistently shown a learning gap associated with students who do not speak the language of instruction in the home (Entorf & Minoiu, 2005; Schnepf, 2007; Trong, 2009). Multilingual countries across the world have different policies for educating the population. For example, some countries have one commonly spoken language, and other countries are a historically multilingual population, and immigration can increase language diversity.

Intended Mathematics and Science Curriculum

Whether formulated at the national, community, or school level, curricular documents define and communicate expectations for students in terms of the knowledge, skills, and attitudes to be developed or acquired through their formal mathematics and science education. The nature and extent of these curricular goals can vary across and within educational systems, and differences also exist in how the curricular goals are kept current in the face of a changing society and workplace, and with technological advances.

Although mastery of the subject typically is a major focus of mathematics and science curricula, countries differ considerably in how mastery is defined and how the curriculum specifies that mastery should be achieved. For example, acquiring basic skills, memorizing rules, procedures or facts, understanding mathematical concepts, applying mathematics to "real-life" situations, communicating or reasoning mathematically, and problem solving in everyday situations are several approaches to teaching mathematics that have been advocated in recent years and are implemented to varying degrees in different countries. In science, focus on acquiring basic science facts, understanding and applying science concepts, emphasis on formulating hypotheses, designing and conducting investigations to test hypotheses, using inquiry-based learning, and communicating scientific explanations are teaching strategies that are emphasized in some countries more than in others. Similarly, differences in the structure of the science curriculum as separate or integrated subjects can result in different experiences for students in different countries.

Teachers and Teacher Education

Policies on teacher education can facilitate the successful implementation of the intended curriculum, and TIMSS collects information about how countries educate teachers in content and pedagogical approaches specified in the curriculum. As described in the *TIMSS 2011 Encyclopedia*, training may be an integral part of the teacher education curriculum or it may be included in professional development programs for practicing teachers.

Monitoring Curriculum Implementation

Many countries have systems in place for monitoring and evaluating curriculum implementation, and for assessing student achievement. Commonly used methods include national or regional standardized tests, school inspections, audits, and teaching observations.

Home Contexts

Parents or guardians and the general home environment are very influential on children's upbringing and their success in school. In order to better understand the effects of the home, TIMSS 2015 will collect data through both the student questionnaire and a new home questionnaire, which will be completed by the student's parents or caregivers. Through these two questionnaires, information will be gathered on the following:

- Home resources for learning;
- Language(s) spoken in the home;
- Parental educational expectations and academic socialization;
- Early literacy, numeracy, and science activities.

Home Resources for Learning

Home resources for learning encompass important socioeconomic characteristics of the parents, such as their education level, together with home supports for learning and emphasis on educational activities. In educational research, the most influential background factors on student achievement tend to be those that measure socioeconomic status of the parents or caregivers, often indicated through proxy variables such as parental level of education, income, occupational class, and, more generally, home resources (Bradley & Corwyn, 2002; Dahl & Lochner, 2005; Davis-Kean, 2005; Martin, Foy, Mullis, & O'Dwyer, 2013; Sirin, 2005; Willms, 2006).

With the evolution of technology, children are increasingly spending time interacting with new digital media like *e*books, tablets, and smart phones (Gutnick, Robb, Takeuchi, & Kotler, 2011; Rideout, Foehr, & Roberts, 2010). Research has shown that parents are generally accepting of children spending their time playing on digital media, including certain video games, because they believe that such activities lead to proficiency with computers and technology, important skills for academic and career success (Takeuchi, 2011). For example, if used correctly, educational applications (apps) for mobile devices and other digital media devices can be effective, supplementary early learning tools for young children (Chiong & Shuler, 2010; Lieberman, Bates, & So, 2009).

Language(s) Spoken in the Home

Students who do not speak the language of instruction in the home can be disadvantaged in learning mathematics and science in school, and often there is at least an initial learning gap because students must learn the concepts and content of the mathematics and science curricula through a new language (Entorf & Minoiu, 2005; Schnepf, 2007; Trong, 2009).

Parents Educational Expectations and Academic Socialization

Parents convey their expectations to their children and provide educational goals for them (Hong & Ho, 2005; Jeynes, 2005). Academic socialization is the process of stressing the importance of education, and includes parents and children talking about the value of education, discussing future educational and occupational expectations for the child, and helping children draw links between schoolwork and its real-world applications (Hill & Tyson, 2009; Taylor, Clayton, & Rowley, 2004).

Academic socialization also can be subject-specific. For example, parents can convey the value they place on science or mathematics, and this can be associated with achievement in the subject (Hong, Yoo, You, & Wu, 2010; Sun, Bradley, & Akers, 2012). Sometimes socialization can be subtle, conveyed by the parents' occupations or hobbies (Dabney, Chakraverty, & Tai, 2013), but it also can be more direct, such as parents encouraging children to participate in particular extracurricular activities and bringing children on field trips or museum visits (George & Kaplan, 1998).

TIMSS 2011 results have shown a relationship between students' educational expectations and their achievement. The socioeconomic status of the parents is highly related to a student's educational expectations, as is the selectivity and composition of the school that the student attends (Sikora & Saha, 2007). Research has found that students may reevaluate their educational expectations over time as they receive more information on their abilities and the opportunities that may be presented, although the extent of this adaptation process continues to be debated (Andrew & Hauser, 2011; Morgan, 2005).

Early Literacy, Numeracy, and Science Activities

In many contexts, reading ability can be essential to learning and achieving in mathematics and science. Early parental involvement in children's literacy activities can impact early literacy development, and have long-lasting effects on children's literacy as they age (Melhuish et al., 2008; Senechal & LeFevre, 2002).

Small children who engage in early numeracy activities in their homes and pre-school can stimulate their interest in mathematics and enhance the development of their abilities (Claessens & Engel, 2013; Melhuish et al., 2008; Sarama & Clements, 2009). These activities include playing with blocks or construction toys, saying counting rhymes or singing counting songs, playing games involving shapes, and playing other types of games that involve quantitative reasoning.

A child's early experiences with science may include visiting the zoo, building things, and visiting science museums. These early experiences could shape both the student's attitude towards science and knowledge of the subject. Students who have early numeracy skills and science knowledge when entering school often have higher achievement in primary school (Duncan et al., 2007; Princiotta, Flanagan, & Hausken, 2006).

In an analysis of TIMSS and PIRLS 2011 data, Gustafsson, Hansen, and Rosén (2013) found that early childhood activities including both literacy and numeracy activities predict student ability when entering primary school and student achievement on the TIMSS subjects at the fourth grade, after controlling for other predictors in a structural equation model. This research found a gender discrepancy in early childhood activities, with parents reporting more early childhood literacy-oriented activities for girls and more early childhood numeracy-oriented activities for boys.

School Contexts

A school's environment and organization can influence the ease and effectiveness of reaching curricular goals. Accepting that an effective school is not simply a collection of discrete attributes, but rather a well-managed integrated system where each action or policy directly affects all other parts, TIMSS focuses on a set of well-researched school quality indicators:

- School location;
- School composition by student socioeconomic background;
- Instruction affected by mathematics and science resource shortages;
- Teacher availability and retention;
- Principal leadership;
- School emphasis on academic success; and
- Safe, orderly, and disciplined school.

School Location

Depending on the country, schools in urban areas may have access to more resources (e.g., museums, libraries, bookstores) than schools in rural areas. In some countries, schools in urban areas may provide for a more supportive environment because of better staffing conditions and the student population coming from economically more advantaged backgrounds (Erberber, 2009; Johansone, 2009). In contrast, in other countries, schools in urban areas are located in neighborhoods with considerable poverty, little community support, and sometimes even in areas of considerable crime and violence (Milam, Furr-Holden, & Leaf, 2010).

School Composition by Student Socioeconomic Background

Since the Coleman report (Coleman et al., 1966), there has been a great emphasis on how the socioeconomic status of the collective students in the school can influence individual student achievement (Martin, Foy, Mullis, & O'Dwyer, 2013; Rumberger & Palardy, 2005; Sirin, 2005). Research has found that a school with many socioeconomically disadvantaged students can be overwhelmed by a culture of futility, in which education and schooling are viewed as an exercise having little or no future (Agirdag, Van Houtte, & Van Avermaet, 2012). The correlation between lower socioeconomic status and lower achievement may be able to be partially explained by other school factors. For example, in some countries, schools with students from lower socioeconomic status are taught by less qualified teachers (Akiba, LeTendre, & Scribner, 2007; Clotfelter, Ladd, & Vigdor, 2010).

Instruction Affected by Mathematics or Science Resource Shortages

The extent and quality of school resources also are critical for quality instruction (Greenwald, Hedges, & Laine, 1996; Lee & Barro, 2001; Lee & Zuze, 2011). These may include resources as basic as well-trained teachers or adequate classroom space and other school facilities (Schneider, 2002). Results from TIMSS indicate that students in schools that are well resourced generally have higher achievement than those in schools where shortages of resources affect the capacity to implement the curriculum. Two types of resources—general and subject-specific—affect curriculum implementation. General resources include teaching materials, supplies, school buildings and grounds, heating/cooling and lighting systems, classroom space, audio-visual equipment such as electronic white boards and projectors, and computers (including tablets such as *iPads*). Subject-specific resources for mathematics and science may include computers and computer software, calculators, laboratory equipment, and instructional materials.

Teacher Availability and Retention

The retention of well-prepared mathematics and science teachers is especially important in countries where there is a scarcity of teachers in these fields. TIMSS studies and other research have shown that in some countries it can be difficult for schools to recruit mathematics and science teachers (Ingersoll & Perda, 2010).

TIMSS 2011 results showed higher achievement for schools that provide good working conditions for teachers. A manageable workload, adequate facilities, and the availability of instructional materials are important ingredients to fostering productive working conditions and promoting teacher satisfaction (Johnson, 2006; Johnson, Kraft, & Papay, 2012).

In addition, a positive school environment can lead to greater teacher job satisfaction and self-efficacy, which in turn can increase student learning (Caprara, Barbaranelli, Steca, & Malone, 2006). Schools can support teachers and increase retention by providing competitive salaries, a reasonable number of teaching hours, adequate workspace, and good equipment. While the physical conditions of the school are important, the social conditions of the school can be essential to retaining teachers and fostering student achievement. Important social factors in a school include a positive school culture, collaboration among teaching staff, and the leadership of the principal (Johnson et al., 2012).

The transition from university to a school teaching position can be difficult. Consequently, in many countries a large percentage of new teachers leave the profession after only a few years of teaching (APPA, 2007; Guarino, Santibañez, & Daley, 2006; Hancock & Scherff, 2010). The extent to which schools take an active role in the acculturation and transition of new teachers may be important for maintaining a stable teaching force. Mentoring programs, modeling of good teacher practice by peers, and induction programs designed by experienced teachers within the school may be important aids to the beginning teacher (Moskowitz & Stephens, 1997; Tillmann, 2005).

Principal Leadership

Although often removed from classroom teaching, research has shown that a principal can affect student achievement. A characteristic of a successful principal is being able to articulate the mission of the school (Witziers, Bosker, & Krüger, 2003). As such, an effective school leader brings coherence to the "complexities of schooling" by aligning the structure and culture of a school with its core purpose (DuFour, Eaker, & DuFour, 2005). This includes guiding the school in setting directions and seeking future opportunities, monitoring that the school's goals are met, as well as building and sustaining an effective learning environment and a positive school climate. Successful principals often are involved in guiding the teaching process as instructional leaders and ensuring that teachers receive the necessary training and development to produce high achievement among the students (Robinson, Lloyd, & Rowe, 2008). Within the constraints of the educational system, it is up to the principal to ensure that the instructional time, and in particular the time devoted to mathematics and science, is sufficient for the purposes of curriculum implementation. It is also up to the principal to oversee school-level instructional policies, such as grouping arrangements.

School Emphasis on Academic Success

Overall, the success of a school also can be attributable to a school's emphasis on academic success, or the school's expectation of academic excellence. TIMSS 2011 results showed an association between academic achievement and the school emphasis on academic success, a construct based on the literature on academic optimism (Hoy, Tarter & Hoy, 2006; McGuigan & Hoy, 2006; Wu, Hoy, & Tarter, 2013). Indicators of school emphasis on academic success include school administrators' and teachers' expectations for successful curriculum implementation and student achievement, parental support for student achievement, and the student's desire to achieve.

Research also has found that teacher collaboration can increase student learning (Goddard, Goddard, & Tschannen-Moran, 2007; Wheelan & Kesselring, 2005). Teachers who discuss their work with colleagues and collaborate in planning and implementing lessons usually feel less isolated and are less likely to leave teaching (Johnson, Berg, & Donaldson, 2005).The collective education of a school's teachers also can be essential to its academic success. From as early as first grade, research has linked the collective teacher education in mathematics in a school to student achievement (Croninger, Rice, Rathbun, & Nishio, 2007), suggesting that collaboration among teachers with strong educational backgrounds can create an emphasis on academic success within the school and facilitate the implementation of the curriculum.

Collective efficacy among the teachers of the school and general trust that faculty members have for parents and students are additional attributes of a well-functioning school (Hoy et al., 2006; McGuigan & Hoy, 2006; Wu et al., 2013). Schools that encourage and welcome parental involvement are more likely to have highly involved parents than schools that do not make an effort to keep parents informed and participating (Jeynes, 2005). High levels of parental involvement can improve student achievement, as well as students' overall attitude toward school (Dearing, Kreider, & Weiss, 2008; Jeynes, 2005; Jeynes, 2007; Taylor, Pearson, Clark, & Walpole, 2000).

In effective schools, the principal and teachers collaborate to ensure that the curriculum is appropriately implemented in the classrooms. In addition to testing and value-added models, research has found that classroom observations and student surveys can provide important information about the effectiveness of teaching practices (Bill & Melinda Gates Foundation, 2013).

Safe, Orderly, and Disciplined School

Respect for individual students and teachers, a safe and orderly environment, and constructive interactions among administrators, teachers, parents, and students all contribute to a positive school climate and lead to higher student achievement (Greenberg, Skidmore, & Rhodes, 2004). The sense of security that comes from having few behavioral problems and little or no concern about student or teacher safety at school promotes a stable learning environment. A general lack of discipline, especially if students and teachers are afraid for their safety, does not facilitate learning and is associated with lower academic achievement (Milam et al., 2010; Stanco, 2012). Schools where there are clear rules and more fairness have atmospheres of greater discipline and safety (Gottfredson, Gottfredson, Payne, & Gottfredson, 2005).

Bullying among students is a threat to the school learning environment. Bullying is aggressive behavior that is intended to harm students who are physically or psychologically less strong, and takes a variety of forms ranging from name calling to inflicting physical harm. Bullying causes distress to victims, leads to low self-esteem, and makes victims feel like they do not belong (Glew, Fan, Katon, & Rivara, 2008), and research shows that bullied students are less likely to achieve in school (Glew et al., 2008; Rothon, Head, Klineberg, & Stansfeld, 2011). With the prevalence of the Internet, cyberbullying is a new form of bullying that unfortunately appears to be common among students, and, like other bullying, leads to low self-esteem, distress, and poor achievement (Mishna, Cook, Gadalla, Daciuk, & Solomon, 2010; Tokunaga, 2010). Unlike bullying, the process of cyberbullying can be shrouded in a cloud of anonymity for the Internet bully.

Classroom Contexts

Because most of the teaching and learning in school takes place in the classroom, successful learning is influenced by the classroom environment and instructional activities. TIMSS 2015 focuses on the following proven practices that improve teaching and learning:

- Teacher preparation and experience;
- TIMSS mathematics and science topics taught;
- Classroom instructional resources and technology;
- Instructional time;
- Instructional engagement; and
- Classroom assessment.

This section benefitted especially from John Hattie's (2009) book, *Visible Learning: A Synthesis of Over 800 Meta-analyses Relating to Achievement*.

Teacher Preparation and Experience

The preparation and competence of teachers is critical (Darling-Hammond, 2000; Hill, Rowan, & Ball, 2005), and prospective teachers need coursework to gain knowledge in the subjects that they will teach and to understand about how students learn, as well as to learn about effective pedagogy in teaching mathematics and science. In mathematics especially, students have been shown to benefit from teachers who have extensive coursework in the subject (Wayne & Youngs, 2003).

In addition to teacher education and training, teacher experience is essential, and the first years of teaching experience are especially important for teacher development (Harris & Sass, 2011; Leigh, 2010). However, research also has found that teachers continue to develop after five years of experience, and that this development can positively affect student achievement (Harris & Sass, 2011).

Content-focused professional development also is important for fostering student achievement in mathematics and science, and exposing the teacher to recent developments within the field. Professional development through seminars, workshops, conferences, and professional journals can help teachers increase their effectiveness and broaden their knowledge (Blank & de las Alas, 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

With education, training and experience, teachers should feel prepared and confident to teach the TIMSS mathematics and science topics. Research has shown that teachers' confidence in their teaching skills not only is associated with their professional behavior, but also with students' performance and motivation (Bandura, 1997; Henson, 2002).

TIMSS Mathematics and Science Topics Taught

A major focus of the implemented curriculum is the extent to which the mathematics and science topics in the TIMSS frameworks are covered in the classroom. TIMSS addresses this question by asking the mathematics and science teachers of the participating students to indicate whether each of the topics tested has been covered in class in current or previous years, as well as the percentage of time in class devoted to each of the TIMSS mathematics and science content domains.

Classroom Instructional Resources and Technology

A growing aspect of instruction is the use of technology in the classroom, and teachers' familiarity and comfort with technology is increasingly important. Teachers' decisions to use technology in the classroom can result from their beliefs, attitudes, and comfort levels, as well as access to training and materials (Mueller, Wood, Willoughby, Ross, & Specht, 2008; Russell, Bebell, O'Dwyer, & O'Connor, 2003).

Computers, tablets such as *iPads*, and the Internet provide students tools to explore concepts in depth, trigger enthusiasm and motivation for learning, enable students to learn at their own pace, and provide students with access to vast information sources. Besides giving students access to the Internet, computers can serve a number of other educational purposes. At the classroom level, some schools are well-equipped with resources so that instruction can be delivered with the support of digital projectors or interactive whiteboard technology. At the student level, while initially limited to learning drills and practice, now computers are used in a variety of ways including tutorials, simulations, games, and applications. Software enables students to pose their own problems, and explore and discover mathematics and scientific properties on their own. Computer software for modeling and visualization of ideas can open a whole new world to students and help them connect these ideas to their language and symbol systems. Instructional video games and interactive simulations have been shown to engage students in mathematics and science, and be associated with student learning and achievement (Kebritchi, Hirumi, & Bai, 2010; Vogel et al., 2006). For computers to be integrated effectively into instruction, teachers have to feel comfortable using them and receive adequate technical and pedagogical support. Nonetheless, research has confirmed the positive effects of the use of computer technology in the classroom on mathematics achievement in particular (Li & Ma, 2010), and student learning in general (Liao & Chen, 2007; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). The nascent research on the effectiveness of instruction using mobile devices like tablets has shown primarily mixed results (Carr, 2012; Looi et al., 2011); the right fit between the technology, the software, and the instruction is essential for implementation.

Calculator use varies widely among, and even within, countries. Many countries have policies regulating access to and use of calculators, especially at the earlier grade levels. Calculators can be used in exploring number recognition, counting, and the concepts of larger and smaller. They can allow students to solve numerical problems faster by eliminating tedious computation and thus become more involved in the learning process. How best to make use of calculators, and what role they should have, continue to be questions of importance to mathematics curriculum specialists and teachers. Research has found that calculator use was positively related to achievement when the calculator was used both during instruction and testing. However, mixed results were found when the calculator was not included as part of the testing process (Ellington, 2003). Overall, students who use calculators tend to have better attitudes towards mathematics than students who do not use calculators (Ellington, 2003; Hembree & Dessart, 1986). With the increasing functionality and accessibility of digital devices such as computers, tablets, and smart phones, the use of handheld calculators may be decreasing as students increasingly use applications to perform the calculations once done only on a calculator.

Instructional Time

At the school level, the relative emphasis and amount of time specified for mathematics, science, and other subjects up through various grade levels can greatly affect the opportunities to learn. Results from TIMSS show that there is variation between countries in the intended instructional time prescribed by the curriculum and the actual time of implementation in the classroom. On average, however, there is very close agreement between the curriculum guidelines and teachers' reports about the implementation. Research has shown that it is especially important that instructional time be used effectively toward the learning goals and not spent on secondary activities unrelated to the instructional content.

Homework is one way many teachers extend instruction and evaluate student learning. The amount of homework assigned for mathematics and science varies both within and across countries. In some countries, homework is assigned typically to students who need it the most. In other countries, students receive homework as an enrichment exercise. Strong students may spend less time on homework because they use their time more efficiently (Trautwein, 2007; Won & Han, 2010). For these reasons, it has been argued that the effect of homework may be better encapsulated by measures of homework frequency than homework time (Trautwein, 2007). In addition, there is evidence homework is more effective for older students and higher achieving students (Hattie, 2009).

Instructional Engagement

According to McLaughlin et al. (2005), student content engagement focuses the student's "in-the-moment" cognitive interaction with the content. "Learning occurs through the cognitive engagement of the learner with the appropriate subject matter knowledge" (McLaughlin et al., 2005, p.5). Engagement can take place when students listen to the teacher, conduct lab experiments, or solve a mathematics problem. Engagement has been conceptualized as the idea that a student's "in-the-moment" mindset is torn between engagement with instruction and distractions that are unrelated to the topics in the class (Yair, 2000). The challenge for the teacher is to use effective methods of instruction to maintain student engagement in the content, activating the students cognitively (Klieme, Pauli, & Reusser, 2009; Lipowsky et al., 2009). A well-managed classroom and a supportive classroom environment can facilitate this engagement process (Klieme et al., 2009; Lipowsky et al., 2009).

Research has shown that effective classroom management allows for better engagement with teaching and learning, and higher achievement outcomes as it focuses the class and instructional time on the topic (Fauth et al., in press; Lipowsky et al., 2009; Marzano, Marzano, & Pickering, 2003; Wang, Haertel, & Walberg, 1993). Effective teachers are strong classroom managers, who build trust with the students and limit disruptions to the instruction (Stronge, Ward, & Grant, 2011). Teachers can be strong classroom managers by ensuring that rules are clear, taking effective disciplinary action, building optimal student-teacher relationships, and maintaining an alert and objective mindset during instruction (Marzano et al., 2003). Effective teachers are able to create an optimal classroom environment by providing clear purpose and "strong guidance" for the classroom while encouraging cooperation among the students and an environment of respect between students as well as between students and the teacher (Marzano et al., 2003). Supportive teacher-student relationships are important not only to foster achievement (Cornelius-White, 2007; Marzano et al., 2003), but also to increase student participation as well as student motivation and interest to learn the subject (Cornelius-White, 2007; Fauth et al., in press).

Motivation can be facilitated, according to self-determination theory (Deci & Ryan, 1985), by creating an environment that fosters a sense of *relatedness*, *competence*, and *autonomy*. A classroom environment that is overly controlling can stifle student motivation because it removes the student's sense of autonomy (Niemiec & Ryan, 2009). Teachers can nurture the development of student motivation in a subject by creating an environment that allows students to work autonomously, while providing support, guidance, and positive feedback (Ryan & Deci, 2000). A socially welcoming school environment or classroom also can provide a sense of relatedness by giving students a sense of belonging (Goodenow & Grady, 1993). Teachers can create this supportive environment by providing positive feedback, listening and responding to students' questions, and being empathetic to students' needs (Reeve, 2002).

Students are more engaged in student-centered learning, when they are working individually or with their peers rather than listening to a teacher lecture or watching a video (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003; Yair, 2000). An effective teacher ensures that students are actively involved in their own learning process. Peer-tutoring, small group work, and peer mentoring are effective strategies that promote student engagement and are linked to achievement (Hattie, 2009; Springer, Stanne, & Donovan, 1999). When comparing cooperative, competitive, and individualistic learning models, research points to the effectiveness of cooperative learning over competitive and individualized learning, although competitive learning does produce better results than individualized learning (Roseth, Johnson, & Johnson, 2008).

Successful teachers engage students in new content by linking the new material and concepts to the students' prior knowledge and understanding (Kleime et al., 2009; McLaughlin et al., 2005). Concept mapping (Nesbit & Adesope, 2006) and advance organizers (Hattie, 2009; Stone, 1983) are two proven strategies for linking prior learned concepts to new concepts.

Students also are more engaged when they are challenged and face greater cognitive demands (Shernoff et al., 2003; Yair, 2000). However, the challenges of the tasks should be perceived to be attainable for the students. In this respect, effective teaching is setting challenging yet attainable goals for each student and supporting the students in reaching the goals (Hattie 2009; Klein, Wesson, Hollenbeck, & Alge, 1999). In setting goals, it is important that students understand the process of achievement, what outcome is expected, and why the goal is important for the learning process (Hattie, 2009; Martin, 2006). Teachers can make their expectations for the outcomes clear through strategies that include mastery learning (Kulik, Kulik, & Bangert-Drowns, 1990) and worked examples (Crissman, 2006). Effective teachers also find means to emphasize the relevance of the learning task (Yair, 2000). A learning cycle that focuses on spaced practice, in which students are exposed to the content in different ways on multiple occasions over time, increases retention of the learned content or skill (Donovan & Radosevich, 1999; Hattie, 2009).

In mathematics, effective teaching strategies include small group learning (Springer et al., 1999), peer instruction (Baker, Gersten, & Lee, 2002), problem-based learning (Haas, 2005), and technology-aided instruction (Haas, 2005). In science, research has shown higher achievement to be associated with the increased frequency of doing hands-on activities in science, student discussion of measurements and results from hands-on activities, and students working with others on a science activity or project as well as with increased frequency of reading textbooks and writing longer answers about science (Braun, Coley, Jia, & Trapani, 2009). Similar to pedagogical theory in other domains, strategies for effective teaching in science include linking new content to students' prior knowledge and interests, collaborative learning strategies, teacher-student questioning interaction, and inquiry-based instruction (Schroeder, Scott, Tolson, Huang, & Lee, 2007). The effectiveness of the science laboratory sessions often depends on how the teacher structures the student learning experience, and how the laboratory experience dovetails with classroom instruction (Singer, Hilton, & Schweingruber, 2006).

Classroom Assessment

Teachers have a number of ways to monitor student progress and achievement. TIMSS results show that teachers devote a fair amount of time to student assessment, whether as a means of gauging what students have learned to guide future learning, or for providing feedback to students, teachers, and parents.

The frequency and format of assessment are important indicators of teaching and school pedagogy, and research has shown that frequent testing can lead to improving student achievement (Başol & Johanson, 2009). Informal assessments during instruction help teachers identify needs of particular individuals, evaluate the pace of the presentation, and adapt the instruction. Formal tests, both teacher-made and standardized assessments, typically are used to make important decisions about the students, such as grades, or about schools for accountability purposes. Teachers use a variety of formats and test a wide range of contents and cognitive skills. The types of questions included in tests and quizzes can send strong signals to students about what is important.

Student Characteristics and Attitudes Toward Learning

An important topic in educational research is the relationship between student attitudes toward a subject and students' academic achievement. In policy circles, there is debate around whether helping students develop positive attitudes toward mathematics and science should be an explicit goal of the curriculum. In educational research, there are numerous theories on how student motivation and confidence can lead to engagement and academic achievement. TIMSS 2015 includes information about the following:

- Student readiness to learn;
- Student motivation;
- Student self-concept; and
- Student characteristics.

Student Readiness to Learn

In order for students to engage in a task or a goal, it is crucial that they are physiologically ready and possess the prerequisite knowledge to engage in the content (McLaughlin et al., 2005). Results from TIMSS 2011 indicated that many students, even in the most developed countries, struggle to pay attention in class due to hunger and sleep deprivation.

Research has identified nutritional problems to be a barrier to student learning, with school breakfast programs suggested as a possible solution (Taras, 2005). Likewise, sleep deprivation has been found to be related to lower achievement (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010), and may be associated with the early start times at certain schools (Perkinson-Gloor, Lemola, & Grob, 2013), as well as the socioeconomic status of the student (Buckhalt, 2011).

In addition to physiological readiness, students also need to have the prerequisite knowledge to engage with the content because "every new thing that a person learns must be attached to what the person already knows" (McLaughlin et al., 2005, p. 5). In other words, for students to learn, they need to be able to connect the new content to prior knowledge.

Student Motivation

In addition to students' readiness to learn, their motivation to learn is essential to academic success. The source of academic motivation and how it can be facilitated within the school, classroom, and home has been a recurrent area of research (Bandura, 1997; Csikszentmihalyi, 1990; Deci & Ryan, 1985). Students have different levels of motivation for each distinct task and subject area.

Most of the literature separates motivation into two distinct constructs: intrinsic motivation and extrinsic motivation. Intrinsic motivation is an "energizer of behavior" (Deci & Ryan, 1985, p.32). Students who are intrinsically motivated to learn mathematics or science find the subject to be interesting and enjoyable (Deci & Ryan, 1985). Although it is theorized that all human beings are born with intrinsic motivation to learn, the home and school can either facilitate or suppress this inner motivation.

Extrinsic motivation refers to the drive that comes from external rewards like praise, career success, money, and other incentives. Research consistently shows that intrinsic motivation is more closely related to achievement than extrinsic motivation (Becker, McElvany, & Kortenbruck, 2010; Vansteenkiste, Timmermans, Lens, Soenens, & Van den Broeck, 2008). Indeed, some research points to external rewards dampening a student's intrinsic motivation (Deci, Koestner, & Ryan, 1999). Nevertheless, most students do not have an intrinsic motivation to learn all subjects, and therefore fostering motivation through extrinsic rewards may be a necessary course of action for a teacher or a parent. In these cases, research has found that successful students internalize their extrinsic motivation to increase performance, in an environment that cultivates feelings of relatedness, competence, and autonomy (Ryan & Deci, 2000; Deci & Moller, 2005).

Student Self-Concept

Students' perceived competence in a subject is linked to their subject specific self-concept. If students believe that academic tasks are outside the scope of what can be completed successfully, students will view the exercise as futile, and this will affect their motivation. In contrast, if students are confident, they are more likely to persevere to successfully complete the school task (Bandura, 1997). Self-concept is often estimated relative to students' peers or experiences, and is a multi-dimensional construct; that is, students have distinct mathematics and science self-concepts (Marsh & Craven, 2006).

Student Characteristics

For decades there has been concern about girls lagging behind in mathematics and science. Currently, the majority of research shows the achievement difference between boys and girls in mathematics and science to be minimal (Coley, 2001; Lindberg, Hyde, Peterson, & Linn, 2010; McGraw, Lubienski, & Strutchens, 2006). TIMSS has shown that there is no large overall difference in average mathematics and science achievement between boys and girls across participating countries, although the situation varies from country to country.