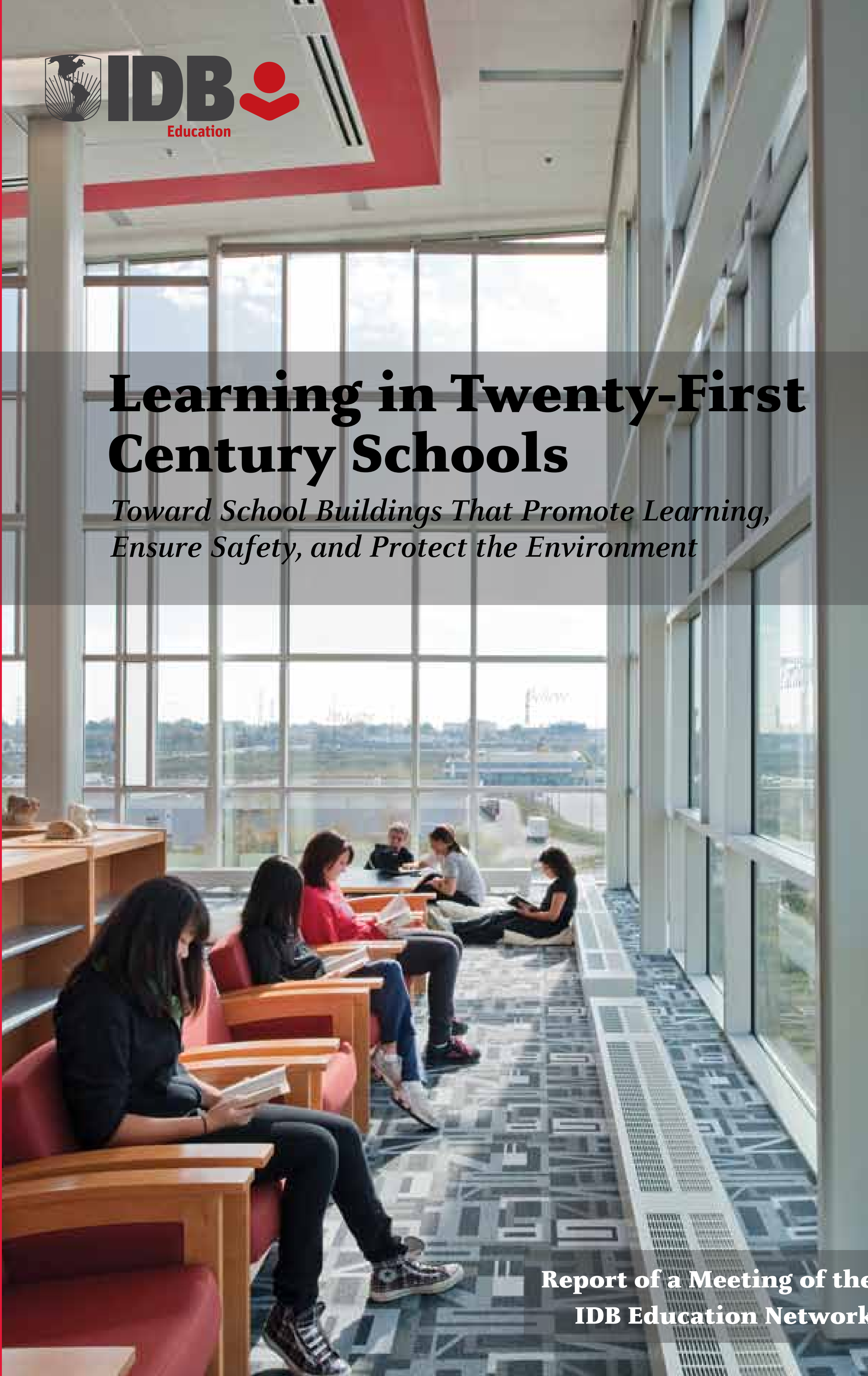
Learning in Twenty-First Century Schools

Toward School Buildings That Promote Learning, Ensure Safety, and Protect the Environment



Report of a Meeting of the IDB Education Network

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Introduction: Learning in Twenty-First Century Schools

In 2006, the Education Division of the Inter-American Development Bank (IDB) created the Education Network under the framework of the IDB Regional Policy Dialogue in order to improve education policies and programs in Latin America and the Caribbean (LAC). Network participants tackle common problems, identifying opportunities for technical cooperation between countries in the region. They endeavor to raise political awareness about the importance of education, increase the efficiency of the sector, promote greater equality in the quality of and access to education, and achieve a safer educational space for students and teachers—one better adapted to the task of providing a modern and high-quality education.

In 2010 the Education Network organized an event that examined the state of school infrastructure in the region and the financial role of the private sector. *Infrastructure and Learning in the Twenty-First Century* was held in Santiago, Chile, on October 26–27, 2010. The IDB's education division and Chile's Ministry of Education invited vice-ministers of education from the IDB's 26 member countries to attend. In all, the meeting attracted 52 researchers, technicians, and decision makers in the area of school infrastructure from 21 countries. After the event, the IDB's education division developed a website so event participants could continue their discussion of common problems related to infrastructure in the education sector. The conference agenda is annex 1 of this book.

This book contains the presentations made at the conference, edited and, in some cases, revised for publication. The chapters of the book follow the conference agenda, which focused on designing, financing, building, and maintaining school buildings. An effort was made to balance international, regional, and national initiatives.

School design. Three sessions were devoted to the design of preschool, elementary, and middle school buildings, with emphasis on research, planning, and developmental theory. Presenters offered past and current design examples from Argentina, Chile, Italy, the United States, and other countries. The studies concluded that spatial configuration, noise level, temperature, light, and air quality affect students' and teachers' ability to perform. Empirical evidence from the United States and Latin America indicates that students attending well-designed and well-built schools outperform students in substandard buildings by several percentage points. (See chapters 1–6.)

Green schools. There is growing evidence that energy-efficient schools have a positive effect on students' learning and health, and on the community at large. Accordingly, a session was dedicated to green schools and their implications in the 21st century. The design of green schools tackles problems such as inadequate daylight, overconsumption of water and other natural resources, low energy efficiency, poor indoor air quality, and safety issues related to antiquated buildings. Green schools also address one of the greatest challenges in human history: climate change. (See chapter 18.)

Preparing for hurricanes and earthquakes. After a brief introduction to the causes and consequences of natural disasters, presenters discussed building codes, engineering designs, and materials and methods of construction specific to schools in areas at high risk of hurricanes and earthquakes. Examples from Italy, Japan, and Mexico were explored. The chief of the emergency team of Chile's Ministry of Education presented a report on Chile's reconstruction following the 2010 earthquake. (See chapters 7–8.)

The impact of school infrastructure on learning. Two sessions adduced empirical evidence to examine the link between school infrastructure and learning outcomes. A report produced by the IDB's education division analyzed variables specific to learning, teacher formation, school-building characteristics, socioeconomic conditions, and others, to shed light on school infrastructure in LAC and its effect on learning. (See chapters 9–10.)

Management and financing of public-private partnerships (PPPs) in infrastructure. Traditionally, the public sector has been the primary source of public infrastructure and services, but most LAC governments have lagged behind in this arena. A morning session was dedicated to PPPs, with the objective of introducing country representatives to various methods of infrastructure financing. The advantages and disadvantages of PPPs were discussed, along with country-specific concessional models and the financial role of various organizations. The Multilateral Investment Fund (MIF) made a presentation showing how it could help in the development of partnership models. (See chapters 11–17.)

This book reflects the contents of the meeting of the Regional Policy Dialogue, where participants discussed national and international best practices in the design and engineering of schools, the impact of school infrastructure on learning, and novel and efficient partnerships between the public and private sector.

Results of the Regional Policy Dialogue

Infrastructure and learning. School infrastructure has a powerful impact on learning outcomes, and policy makers at the meeting voiced a strong commitment to incorporating this fact into their programs. The IDB should continue to finance projects related to school infrastructure in the LAC region, while also supporting projects at the subregional level that are closer to the country or community. The presentations and ensuing discussions revealed discrepancies in learning outcomes in private and public schools, as well as in rural and urban ones. They also suggested that, in general, the science lab, computer room, library, and music and arts room were more conducive to learning than other spaces in schools. For schools in rural areas, improvements in the provision of potable water and sanitation, and public services (such as electricity and telephone) are crucial.

Regulations. The discussions revealed no firm definition of what constitutes education planning and building in the countries of the region; indeed, the lack of common norms and standards for the improvement of school infrastructure was the main topic of discussion. Participants agreed that a set of general codes and regulations should be created and implemented for the creation of infrastructure, along with rules for its conservation and maintenance. Development of these norms should be viewed as long-term investments rather than additional costs.

Security. School security and vandalism were common themes in most sessions. LAC schools need police officers, security cameras, and metal detectors, but their presence should not dictate the school environment. The combination of a participative community and school designs that do not have blind spots should foster security and an environment conducive to learning.

Knowledge gap on green infrastructure. Several LAC countries lack knowledge on the benefits of green or sustainable buildings. The session on green schools served as an incentive for policy makers to place the environment at the forefront of new infrastructure initiatives that generate a sense of social responsibility and lead to financial sustainability and student success. Likewise, schools can hold green education sessions to raise environmental awareness.

Public-private partnerships. The public sector alone cannot close the infrastructure gap, improve the quality of facilities, and build greener schools. But a wide repertoire of financing options is available. The roles of the public and private sectors in establishing policies, regulations, costs, operation, financing, and ownership arrangements needs to be reevaluated to determine the best options for providing high-quality school infrastructure.

Presentations on this topic were eye-openers for many countries, especially Barbados, Chile, Colombia, Costa Rica, Jamaica, Mexico and Trinidad and Tobago. Follow-up activities were planned, including a regional application to the Regional Public Good (RPG) program of the IDB and a possible continuation of the Regional Policy Dialogue in the same area. The studies originated in the RPG program will help to identify private sector associates, establish long-term strategic relationships, and form agreements on specific projects.

During the seminar the intervention of the MIF prepared the ground for further actions. These include using MIF grant resources to finance human capital development within government institutions and creating or strengthening PPP units within the Ministry of Education to enable planning, design, and administration of PPP projects and to support reforms in the legal framework.

As a corollary of this conference, the IDB hopes to increase awareness of the importance of infrastructure both in the traditional sense of improving access as well as in the modern sense of providing better spatial configuration and greener (more energy efficient) buildings, which have been shown to have a positive effect on learning. Furthermore, a dialogue needs to be initiated about the importance of involving the private sector to create more and better-quality school buildings.

Next steps

The IDB has pledged to provide initial financing for a permanent forum on regional policies and practices related to school infrastructure. To this end the LAC region presented, with the support of 12 countries, a proposal for a regional technical cooperation (TC) to finance a series of technical meetings on the topics raised in this book, with the goal of consolidating regulations and standards related to educational facilities in the 21st century. That proposal was approved in January 2012 in the amount of $1.4 million, and work is progressing on schedule.

The regional TC will support the development of innovative practices for financing and managing school infrastructure while also developing public institutions and improving cooperation between the private and public sectors. Finally, it will aim to develop awareness, in each of the participating countries, about the costs and benefits of greener schools, compared with traditional buildings. A mapping of school infrastructure conditions in the different countries will also be encouraged. The TC will serve to motivate participant countries to implement school-mapping exercises.

More policy dialogue will be necessary to cement the importance of changing school designs to create more flexible and greener school spaces that better serve the needs of modern pedagogy. This can be accomplished by creating new hemispheric dialogues in which school facilities, violence prevention, and related topics can be discussed.

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PART 1

Preschool and Kindergarten Designs

1

The Influence of Design on Learning Outcomes

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John Dewey believed that children learn best by doing, a concept extended in the Reggio Emilia and Montessori approaches, both of which recognize the role of the physical environment in shaping how young children acquire knowledge. To create preschools and kindergartens in which the physical environment is closely integrated with pedagogy and assists both teaching and learning, architects must consult educational theory and practices, study learning environments, and examine architectural precedents to understand which architectural features of schools best encourage children's engagement and which are counterproductive.

Understanding how the physical environment influences and shapes learning requires a comprehensive approach to the programming, planning, and design of schools—an approach in which research plays an integral part. Research can inform the designer about the "transactional nature" of the learning environment—that is, how the physical environment affects the learner. Examples of such research include Barker and Gump (1964), Lippman (1997), and Kennedy and Moore (1998).

Before designers create a preschool or kindergarten, they must understand the social and emotional advancements that children are making during these years. In addition, they must understand how influential pedagogical theories—such as constructivist theory and practice theory (Lippman 2011)—describe the role of the physical environment in the learning process. Such understanding helps architects become informed and effective advocates for design innovation.

Guidelines for the design of learning communities

This chapter provides guidelines for the design of 21st-century classrooms and entire learning communities. Grulke, Beert, and Lane (2001) propose the concepts of *personalization* and *ability to manage interactions*. Two more concepts—of *flow* (or transition) and of *layered spaces of variable size*—are recommended by Lippman (2011; 2004). A fifth concept, *place attachment*, is derived from Low and Altman (1992).

The concepts and guidelines described above suggest attributes of learning environments that support the variety of ways in which people learn. While relevant to all learning environments, they are fundamental for planning and designing preschools and kindergartens.

Personalization and managing interactions

Personalization is required to create spaces in which all members of the learning community are enabled, engaged, and empowered to acquire knowledge and master skills. The learning, social, and physical environments are understood as working together to encourage learning. In a personalized setting, teachers are encouraged to work cooperatively with one another as they develop a curriculum and pedagogy to support and guide their students. The personalized school is also a place with an evolving educational program, where students are encouraged to develop and connect with teachers and their peers.

The social component of the learning environment is widely acknowledged to be essential in encouraging cooperative work and promoting an integrated learning environment, but the role of the physical environment is often ignored or misunderstood. This is unfortunate, because the physical environment is the vehicle that reinforces the mission and vision of the school.

Properly planned and built, the physical environment amplifies and enhances the diverse ways in which people learn. It is crucial for creating an environment that may be characterized as personal—for example, by creating zones in schools where teachers and students have the opportunity to be engaged peripherally, such as by clustering classrooms around a common area. Within the common area, the spaces must be attached to specific instructional spaces. By connecting these two spaces, a learning zone is created that is owned, maintained, and can become personalized by the learners from a particular classroom. Furthermore, these learning zones and activity settings become places that tie students to a classroom and allow them, as they use the space, to connect with others from other classrooms. Another possible activity setting might be a grand staircase where people can meet informally as they move from floor to floor. This design feature can also be a place where members of the learning community can gather formally (for presentations or assemblies involving the entire school) or meet informally to work on projects.

The ability to manage interactions refers to the ease with which learners and teachers can become engaged, formally or informally, in independent or cooperative activities. The concept also refers to how learners are able to obtain, retain, and use the tools and resources in their learning environment to solve the problems at hand. Knowing that people can move from a position of being fully engaged to peripherally engaged (or vice versa), the physical environment must have features that promote opportunities for learners to manipulate their environment to support the ways in which they choose to work. In addition, managing interactions involves how learners and their peers and teachers (the social environment) perform the following tasks:

- Arrange the furnishings in the setting "sociopetally" (meaning connected to one other, as in a circle) or "sociofugally" (meaning separate from one another, as with airport seating) (Osmond 1966)
- Manage the air temperature in the zones in which they are working
- Adjust the light in the zones in which they are working
- Work together to manage noise levels in their working zones.

Layering

Layered spaces are defined learning spaces. When formal and informal activities are allowed to extend beyond those spaces into the learning zones that are attached to them, the settings expand to create places where activities can overlap. Layered spaces are variable in size and support opportunities for individual, one-to-one, small-group, and large-group transactions. Examples of such spaces are discussed below.

- *Gathering spaces* are generally moderate to large areas in the learning community, or common areas where large groups. These may be inside or outside the facility. Inside the facility, gathering spaces may be outside instructional spaces or offices.
- *Planning spaces* may be medium-sized learning zones where small groups can come together and share information about the projects on which they are working. These include teacher workrooms, learner breakout rooms, as well as conference rooms.
- *Resource spaces* are large spaces in the learning community, such as media and technology rooms and faculty offices.
- *Production spaces* are moderate to large learning zones where learners construct projects.

- *Practice spaces* are smaller learning zones—areas where students develop practical skills that may be transferred to other settings outside the learning community. Science laboratories, for example, are places where students learn to use specialized equipment.
- *Presentation spaces* are small to mid-sized areas where students' work is displayed and where students may present their projects.
- *Community spaces* are generally the largest places in the learning community. Examples include the gymnasium, cafeteria, media center, auditorium, and theater.
- *Formal/direct instructional spaces* are moderate to large learning zones, such as classrooms and seminar rooms.
- *Informal instructional spaces* are learning zones that may be found anywhere in the learning environment. They include places where active learners develop scientific knowledge from everyday experience.

The list above identifies the types of learning zones needed to encourage, promote, and support the various ways in which learning occurs. While this list differentiates specific spaces to accommodate particular activities, each area is properly considered in relationship to the others.

Flow and transition

Flow and transition refer to the situated nature of learning—the "between time" spent in motion, or the fifth dimension—the realm of students' relationship with space and their transactions with others in space. This term, *flow and transition*, addresses the notion that learning and teaching should not be understood as static but rather as dynamic. For this reason, the entire learning facility must be programmed and planned to promote opportunities for extending both teaching and learning beyond formal instructional spaces (Lippman 2007). As students move between the spaces in the school, the spatial design must provide for transitions from one place to the next. These transitional features should highlight how particular activity settings are intended to be used. For example, changes in the type of furniture, or the presence or absence of furniture, can encourage or discourage certain activities. Chairs and tables with casters can be moved between spaces to encourage a variety of social gatherings. Countertops with stools may support independent work, whereas chairs that allow rocking encourage students to become fully engaged in activities at hand by dissipating their natural nervous energy.

Place attachment

Place attachment promotes opportunities for privacy, personal displays, security, and serenity (Low and Altman 1992). The notion may also refer to opportunities for the learner to be creative and master both informal and formal skills in the learning environment. Because time spent in the learning community is limited, its physical environment should enable learners' to make the most of it by promoting a sense of peace and positive self-identity. Serenity may be achieved by giving learners areas for reflection and engagement, which typically include private and independent working areas. When such places are available, learners are less likely to feel stressed, because they have a space where they can accomplish their work (Lippman 1995; Oliver 2004; Oliver and Lippman 2007).

Examples of the application of these principles

The innovative preschools and kindergartens profiled below offer contemporary examples that promise to shape the future development of learning environments. They were chosen because they were planned and designed around the complementary notions that the learner is an active participant in the learning process and that the physical environment, too, should be understood as active.

Figure 1.1. Atelier, Loris Malaguzzi Infant School, Reggio Emilia, Italy. Children working in the atelier remain connected to others

Photo: Tullio Zini Architetto and ZPZ Partners

Loris Malaguzzi Infant School, Reggio Emilia, Italy

Year of completion: 2008
Architect: Tullio Zini Architetto and ZPZ Partners
Pupils: 90

Named after the teacher and psychologist who developed the Reggio Emilia pedagogical approach, the school comprises an exhibition hall and research center. Flexible classrooms contain a variety of activity settings that allow for the management of interactions: an atelier area for creative work (figure

Photo: Tullio Zini Architetto and ZPZ Partners

Figure 1.2. Piazza, Loris Malaguzzi Infant School Reggio Emilia, Italy.

1.1), a laboratory for studies centering on science and technology, and a piazza for performance and physical play (figure 1.2). The piazza supports assemblies and performances but may also be used for small-group and independent learning. Flexibility is achieved by movable furniture and shelving so that the room can support a variety of activities simultaneously. Extensive storage is thoughtfully integrated into the learning environment, with storage units functioning as walls that create possibilities for informal games. Personal storage areas for each child and a mezzanine level in each classroom, where children nap, create place attachment (figure 1.3). Connections are established by the stairs to the loft space, interior glass, exterior glass, and built-in storage. This room can support a variety of activities simultaneously, since the furniture and shelving are easily moved. In these instructional spaces, students can manage their interactions, choosing what activities to perform and with whom to work.

Photo: Tullio Zini Architetto and ZPZ Partners

Figure 1.3. Classroom, Loris Malaguzzi Infant School, Reggio Emilia, Italy

Little Stars Childcare Centre, Melbourne, Australia

Year of completion: 2009
Architect: Graypuksand
Pupils: 75

Located in Melbourne, Little Stars Childcare Centre is an extraordinary example of how good design can overcome challenges—in this case the challenge of being located on the first floor of an old and recently refurbished office building. The renovation of the facility extended the facade to provide a landscaped outdoor space (figure 1.4). Designed as a center-city childcare facility for the children of employees of the National Australia Bank, it provides interior and exterior play areas, sleeping facilities, and supporting amenities such as a fully equipped kitchen, manager's office, reception desk, and staff breakout area. The outdoor play area integrated into the design ackowledges the importance of physical activity for young children. It also helps them learn how to negotiate space.

A sense of flow was achieved by selectively placing glass in the walls. This established visual connections throughout the numerous spaces, encouraging a sense of personalization. Children and staff have the opportunity to get to know one another by seeing each other work, learn, and play in different areas, with peripheral, guided, and full engagements achieved via other salient features in the physical environment. These features

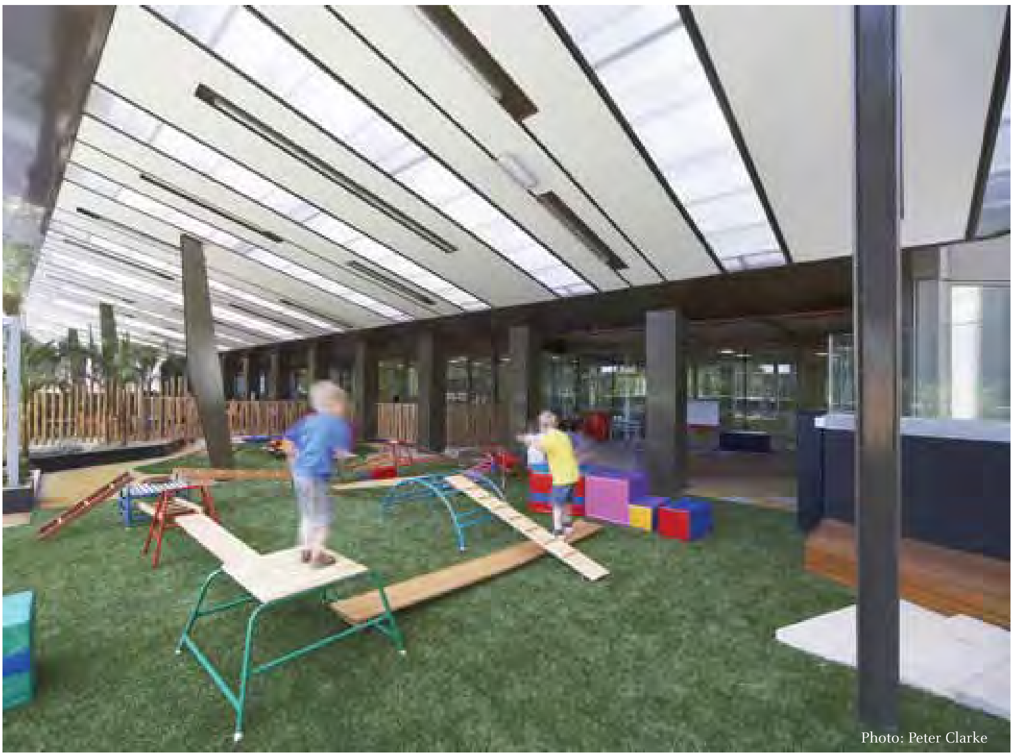

Photo: Peter Clarke

Figure 1.4. Outdoor space, Little Stars Childcare Centre, Melbourne, Australia

Figure 1.5. Classroom, Little Stars Childcare Centre, Melbourne, Australia

include child-height tactile surfaces, seating built into the window walls (where individuals or small groups can sit and observe activities beyond the boundaries of their play areas and classrooms), and "pods" that provide a quiet haven where children can rest, read, or play independently. Wall seating encourages independent and one-on-one learning opportunities, without separating learners from others (figure 1.5).

Skanderborggade Day-Care Center, Copenhagen, Denmark

Year of completion: 2005
Architect: Dorte Mandrup Arkitekter
Pupils: ~50

The Skanderborggade Day-Care Centre is an extraordinary example of how good design can overcome serious constraints—in this case the shortage of light, particularly in winter.

Lighting studies mapped the sun's path at different times of the year, particularly through the long northern winters, so that optimal light levels could be achieved on the ground floor. A pleasant and comfortable sense of flow was achieved by creating a series of courtyards, each with a specific environmental quality but connected to the next. A yard in the quietest corner of the center was set back from the street, shaded by trees to reduce temperatures, and designed for relaxing and sleeping in the summer months. The central, curved courtyard and rooftop play space were designed to maximize daylight for playing outdoors year round (figure 1.6). Nursery bays, promoting

Figure 1.6. Entrance elevation, Skanderborggade Day-Care Centre, Copenhagen, Denmark. The building is located comfortably in its urban site

personalization, are clustered around a common area that is part of the central lobby and connects the rooms. The central lobby fosters opportunities for peripheral, guided, and full engagement among staff and learners.

Springfield Literacy Center, Springfield, Pennsylvania, United States

Year of completion: 2010
Architect: Burt Hill (a Stantec company)
Pupils: 350

The Springfield Public School District embraced an alternative model for literacy education known as the individual literacy program. To support the implementation of that program, the Springfield Literacy Center required a variety of activity settings throughout the school so that learners and teachers could manage their interactions, engaging in one-to-one and collaborative small-group instruction in classrooms and other areas. The kindergarten and first-grade classroom wings are arranged along single-loaded corridors (figure 1.7), affording flexible, multifunctional spaces outside the instructional settings.

Figure 1.7. Site plan, Springfield Literacy Center, Springfield, Pennsylvania, United States. The floor plan implies that learning extends through the building and onto the site

The library is the first space that learners encounter. It tells them that everyone can learn to read enjoyably (figure 1.8). Spaces for small-group instruction are located between classrooms, exemplifying the concept of flow; they are separated by sliding barn doors that define specific activity settings. Windows in the doors enable learners to remain peripherally engaged in the activities beyond. The face of the school (figure 1.9) lets children know that nothing is beyond their reach.

Figure 1.8. Lobby and library, Springfield Literacy Center, Springfield, Pennsylvania, United States

Figure 1.9. Elevation, Springfield Literacy Center, Springfield, Pennsylvania, United States

The Montessori School, Kingsley, Australia

Year of completion: 2010

Architect: Edgar Idle Wade Architects

Pupils: 182 students (56 early childhood students, 40 lower primary students, 40 upper primary students, 30 lower secondary students, and 16 upper secondary students)

This Montessori school complex in western Australia has primary and secondary buildings as well as an early childhood building. The classroom buildings are clustered to create shared common areas between the structures. Each of the buildings and the complex are good examples of layered settings. The spatial design of each classroom building offers differentiated learning zones (or activity settings) that can expand and contract depending on the project at hand and the number of learners engaged in a particular task. In the layered classroom shown in figure 1.10, the walls provide the resources and tools students need.

The floor plan is organized as a series of nested, concentric learning zones. Resources and tools are stored along the perimeter walls, creating a zone that offers the learner a variety of learning choices, such as books and blocks. As learners select tools they move from a private zone to a semi-private zone in which they can share tools with one another.

At the center of the room is the most public zone, where the entire class can meet. Within all zones, students may learn individually, in pairs, in small groups, or as a whole, with or without teacher guidance. The buildings also have multiple usage patterns that are intended to attenuate the teacher-student hierarchy.

Each classroom is linked to an outside space, affording opportunities for gardening and nature activities. Students can move freely between buildings and spaces to engage in peer-to-peer learning and self-directed investigation based on experiential activities.

The buildings were designed for passive sustainability. Their southeast orientation, operable windows (for cross ventilation), thermal mass walls, clerestory windows (for sunlight in winter), and rain-water collection tanks all support that goal. The decision to use passive solutions will have a direct effect on the life-cycle costs of the building. With no mechanical heating or cooling systems to maintain, funds that would otherwise have been spent on these systems can be used to advance the educational programs.

Figure 1.10 . Classroom, The Montessori School, Kingsley, Australia

Fuji Kindergarten, Tokyo, Japan

Year of completion: 2007
Architect: Tezuka Architects
Pupils: 500

The largest kindergarten in Japan, Fuji Kindergarten affords a learning environment that encourages individual development and expression for all its pupils, utilizing the concepts of place attachment and flow. Montessori pedagogy guided the planning and design of the building. The "roof house"—an oval-shaped play deck—is used throughout the year, primarily for informal play, but also for more formal learning and assemblies. The design also incorporates three Zelkova trees, a slide from the roof, and water taps for outdoor play. The plan makes each classroom space visible and encourages an open teaching approach in which it is not uncommon for children to mix during lesson times. The building encourages a choice of interactions for learners. Classroom spaces, play areas, and support facilities flow into one, offering a landscape for children to investigate and adapt to their needs. The intention of the design was to provide a safe and secure setting to which learners will become attached and where they can be creative as they master skills.

Conclusion

As architects and designers strive to design learning environments for the 21st century, they must be *responsive* in their approach. To do that, they must develop a better understanding of educational theory, research on learning environments, and architectural precedents. Specifically, design professionals must understand how young learners acquire knowledge so that they can be more effective in creating places that inspire and motivate, even at the cost of challenging architectural standards and practices.

Preschools and kindergartens must be understood as places of inspiration and fun, where a child's innate learning skills are nurtured and developed. In these settings, the young learner is an active, motivated, and wilful participant. The school environment, therefore, must serve as a vehicle for learning, providing a variety of settings for the child to explore. Furthermore, it must support the diverse ways in which children master the skills they need to understand the complex world in which they live. Similar strategies for the design of the learning environment can be adapted and carried over to elementary and secondary schools to diversify and enrich the learners' educational experience.

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2

Architectural Precedents in Preschool and Kindergarten Design

R. Thomas Hille, AIA

The legacy of modern school design provides us with a wealth of innovative ideas and solutions directly related to the design of today's preschools and kindergartens. For well over a century, educators, school planners, and architects have collaborated to create inspiring places for learning based on new approaches to education—approaches that encourage young children, in particular, to more fully realize their developmental potential. This chapter is an introduction to this significant body of work, the study of which is essential for understanding the architectural potential of this important project type, and future directions for its development.

The chapter begins with a brief overview of new educational approaches that have affected the design of preschool and kindergarten learning environments in the modern era. We then offer a representative sampling of the significant preschool and kindergarten designs that have resulted from the response to those approaches, emphasizing the underlying design themes and unique architectural features that characterize them. The chapter closes with a summary of related program criteria that provide a point of departure for the future development of preschool and kindergarten design.

Educational theory, practices, and methods

Historically, the most significant innovations in modern school design are those related to parallel developments in educational theory and practice, developments designed to broaden and enrich the school learning experience. At the preschool and kindergarten levels, where learning activities are inherently diverse and varied, educational theory posits that learning should be active, learner centered, applied, holistic, integrated, diverse, and ongoing.

Related educational practices and methods have been developed over time to complement traditional approaches to learning, which tend to be more formal, hierarchical, and structured. Today, these are generally accepted in educational practice as complementary approaches that can be used to enhance and broaden the learning experience, especially at the preschool and kindergarten levels. Those approaches include activity-based learning, self-paced learning, auto-learning, interdisciplinary learning, applied learning, and cooperative learning.

Design themes

Architectural design themes that characterize innovative learning environments today are directly related to ongoing developments in educational theory and practice. They are typically identified and developed as part of the programming and planning process, when designers work with clients and users to identify their needs. The prioritization of themes is project specific and has a direct influence on the design outcome. Some of the more important design themes that have special implications for preschools and kindergartens are school identity, community use, a variety of learning activities, flexibility and adaptability, social interaction, and the quality of the learning environment.

Architectural precedents

The preschools and kindergartens featured here exemplify these design themes and the characteristic architectural features that result from them. All are from Europe and North America, where the school reform movement began and had its most significant impact over the course of the past century.

Early 20th-century preschool and kindergarten design

Notable examples of innovative preschool and kindergarten design from the early part of the 20th century incorporate many features relevant today (figure 2.1). Features related to the quality of the learning environment include natural daylight; intimacy of scale; a variety of colors, textures, and material finishes; and flexible furnishings. To support a variety of learning activities, the ideal classroom is articulated with a main group activity room, a separate alcove for individual activities, separate washrooms, storage and service areas, adjacent outdoor classrooms, adjoining gardens, and separate outdoor play space. The minimum area for a kindergarten classroom was recommended to be 1.5 or 2 times that of a standard classroom.

Amsterdam Montessori School, Amsterdam, Netherlands

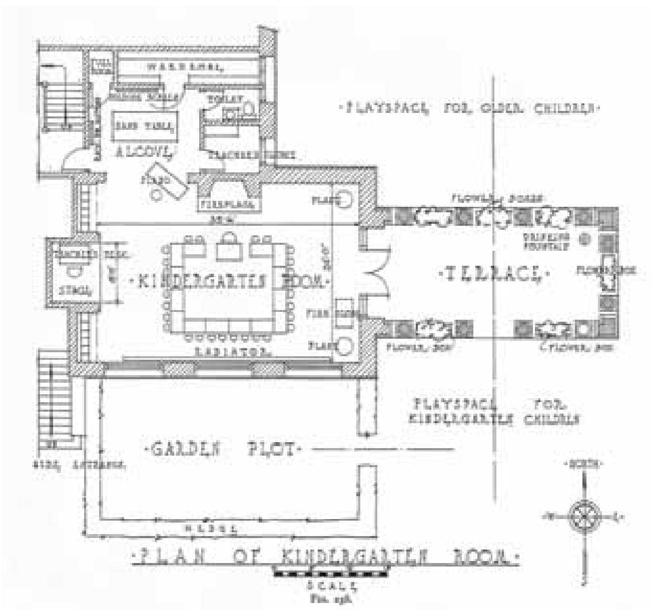
To promote a variety of learning activities associated with Montessori principles, this preschool incorporates a wide array of indoor and outdoor learning venues for formal and informal everyday use. The tightly constrained urban site mandates a vertical organization with two south-facing classrooms raised above street level (figure 2.2). The articulated classroom includes a dedicated group-activity area, a reading corner, a kitchen, built-in work counters and window seats, a south-facing balcony, and a separate wardrobe and washroom. Other special features include a rooftop project room and greenhouse; a ground-floor multipurpose room; a south-facing courtyard with student gardens, a frog pond, and related outdoor activity areas; and a small gymnasium. Throughout the school, built-in features such as blackboards, window seats, and counters are at child height for scale and functionality.

Bruderholz School, Basel, Switzerland

To enhance the functional and aesthetic quality of the learning environment, this early pavilion school in a park-like setting optimizes access to sunlight, fresh air, and the out of doors (figure 2.3). Single-story classroom wings are south facing, providing direct access to a series of intervening landscaped courtyards that accommodate a variety of outdoor class activities. To provide a sense of both identity and autonomy, the kindergarten occupies its own pavilion and courtyard, with direct access from both the neighborhood and school. All classrooms feature controlled bilateral natural light for flexible use, with full-height windows facing south and secondary clerestories facing north. The classroom's direct access to an adjoining courtyard encourages outdoor activities and connections to nature, which are especially critical for learners of kindergarten age.

Figure 2.1. Early 20th-century preschool and kindergarten design

Photo: John J. Donovan, 1921. School Architecture: Principles and Practices. Norwood, Mass.: Norwood Press.



Architects: William B. Ittner and John J. Donovan.

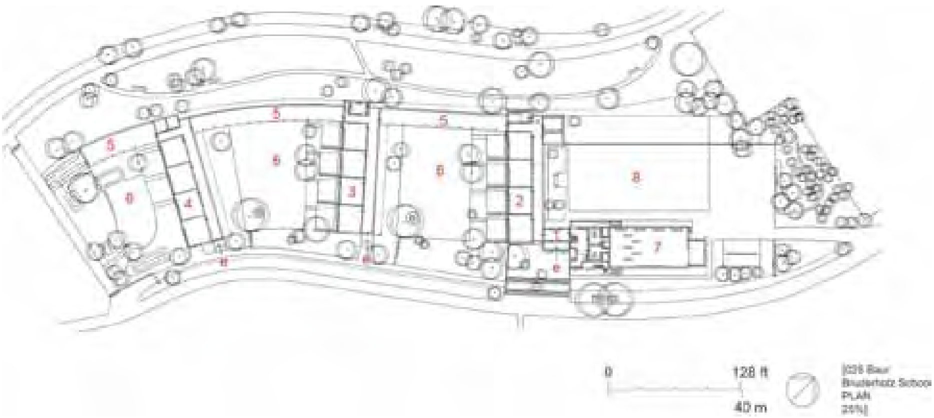
Figure 2.2. Amsterdam Montessori School

Photos: © R. Thomas Hille, all rights reserved.

Architects: Willem Van Tijen, Mart Stam, and Lotta Beese, 1935.

Figure 2.3. Bruderholz School, Basel, Switzerland

Photos: © R. Thomas Hille, all rights reserved.



Architect: Hermann Baur, 1939.

Sant'Elia Nursery School, Como, Italy

The courtyard organization of the school provides a variety of learning venues that focus inward to promote privacy, security, and a sense of identity (figure 2.4). For social interaction, interior spaces throughout the school are open, interconnected, and flexible. Special features include an open central hall that serves as a shared indoor activity area; an adjacent dining hall for communal dining; classrooms with operable partitions that promote interaction between classes and the school's common areas; and wide expanses of glass, offering sunlight and visual connections to adjoining outdoor activity areas. The central courtyard provides natural light and serves as a visual focus for the school. Additional play areas are located on the roof.

Figure 2.4. Sant'Elia Nursery School, Como, Italy

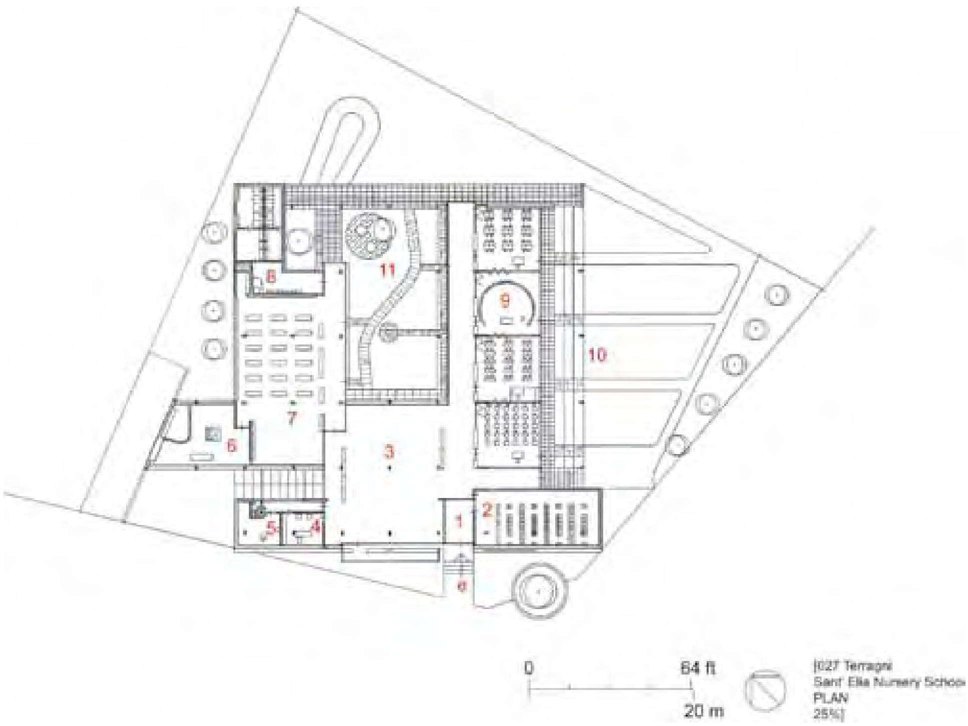


Photo: © R. Thomas Hille, all rights reserved.

Architect: Giuseppe Terragni, 1937.

Crow Island School, Winnetka, Illinois, United States

The design of the school emphasizes child-centered learning, with the classroom providing a home-like environment tailored to the special needs of the individual. The articulated L-shaped classroom incorporates a variety of activity spaces, including a large group activity area and teaching wall; an open project area; a story corner with a south-facing bay window and views into the adjacent courtyard; and a separate side workroom with adjoining toilet facilities and storage (figure 2.5). For identity and autonomy, the kindergarten and nursery classrooms are in a separate wing that has its own entrance. Among the special features of the kindergarten and nursery classrooms are a large group activity area that supports varied uses; a special project area and workshop; a playhouse for younger children; and a shared service area with toilet facilities and a kitchen. The classroom learning environment is comfortable and home like, with furniture and fixtures scaled to the size of the small child.

Figure 2.5. Crow Island School, Winnetka, Illinois, United States

Photos: © R. Thomas Hille, all rights reserved.

Architects: Eliel and Eero Saarinen with Perkins Wheeler and Will, 1939.

UCLA University Elementary School Nursery and Kindergarten, Los Angeles, California, United States

In response to a mild climate and unique natural site, this combined elementary school and nursery-kindergarten promotes the psychological benefits of learning in close association with nature, while accommodating the widest possible variety of learning activities. To provide both easy access and a sense of autonomy, the kindergarten-nursery occupies a separate wing with its own entrance. Five east-facing classrooms, which open out along a wooded ravine, are open and flexible, with large sliding window walls that dramatically connect the interior spaces to nature and the out of doors. A series of outdoor porches and play terraces further integrate the outdoor learning environment and natural setting (figure 2.6).

Figure 2.6. UCLA University Elementary School Nursery and Kindergarten, Los Angeles, California, United States

Photos: © R. Thomas Hille, all rights reserved.

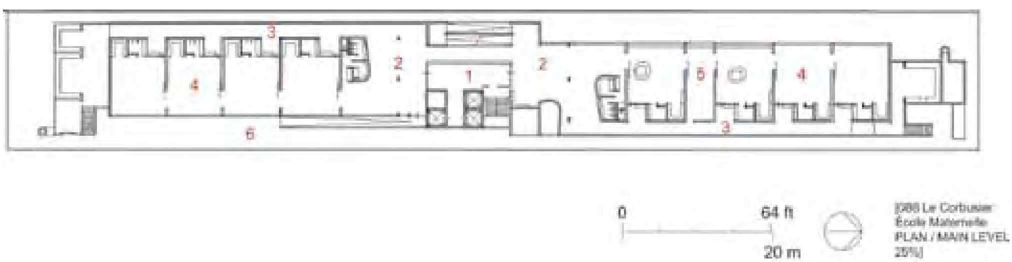
Architects: Neutra and Alexander, 1957.

École Maternelle, Firminy, France

To facilitate community use, this nursery and preschool is integrated into the top floor of a 400-unit utopian housing block (figure 2.7). Two opposing classroom wings are organized along single-loaded hallways, with a shared common space in between for group activities. Special features include sliding partitions that open to connect classrooms and their activities; child-scale fixtures and appointments throughout; outdoor activity areas on the roofs, with views of the surrounding countryside; and a shared workroom on the floor below for project-based learning. Architecturally, the creative use of light and color visually enliven the interior spaces and clarify different activity zones in the classroom and adjoining common areas.

Figure 2.7. École Maternelle, Firminy, France

Photos: © R. Thomas Hille, all rights reserved.



Architect: Le Corbusier, 1967.

Delft Montessori School, Delft, Netherlands

In response to the Montessori program, this school is designed as an interactive learning environment that promotes individual development through independent and self-directed learning. To encourage social interaction, the school is organized like a community, with special zones of interaction between the private domain of the classroom and the more public domain of the hallway. The L-shaped classroom is decentralized in its organization, with a main group-activity area along the outer window wall and a secondary project area inside by the entrance. The kindergarten addition has a similar organization, with two classrooms opening onto a shared hallway, which incorporates a variety of secondary activity areas, services, and storage (figure 2.8). The modified L-shaped classroom includes a larger, more flexible group activity area; an expanded project area; built-in display cases and shelving for teaching materials; window seats and work counters; and a special corner alcove and loft with a hidden escape hatch to the hallway.

Figure 2.8. Delft Montessori School, Delft, Netherlands

Photos: © R. Thomas Hille, all rights reserved.

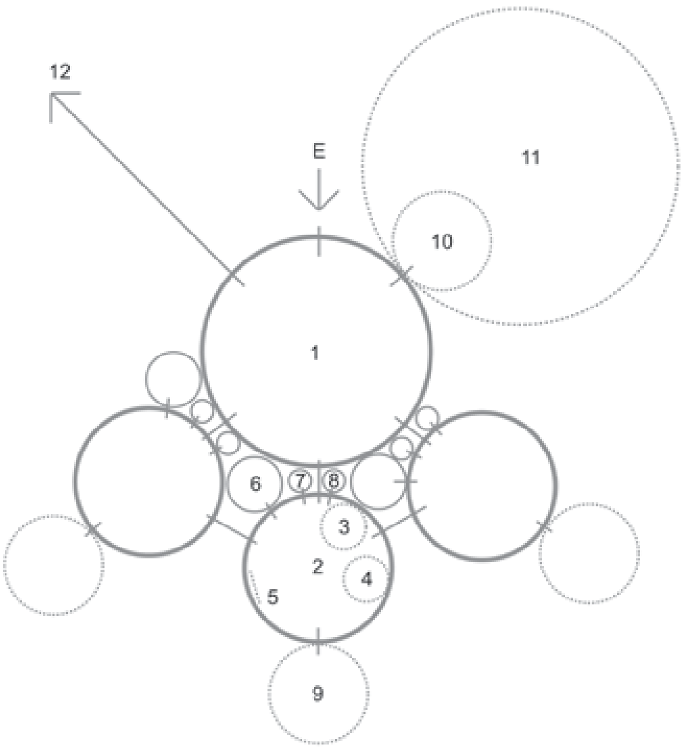
Architect: Herman Hertzberger, 1966–81.

Program criteria

From the study of architectural precedents, preliminary program criteria for preschool and kindergarten facilities can be developed. In practice, these can be modified and adapted as necessary to reflect specific program needs.

- *Classroom.* Classrooms should provide 3.5–5 square meters (m^2) per student. A classroom for 20 students, therefore, should be 70–100 m^2 in size. Program space should comprise a main group activity area, individual and small-group activity zones, a separate quiet room or workroom, a separate washroom, a coatroom/vestibule, and an outdoor study area. Classrooms should be comfortable, inviting, and home like, but flexible in arrangement and featuring a variety of materials, colors, and textures. They should have natural light, views, and direct access to the outdoors.
- *Shared common area.* The school should have a shared common area that is at least the size of two classrooms (140–200 m^2). It should have a clear sense of identity, a large-group activity and reception area, direct access from classrooms, and a separate outside entrance leading to an outdoor play area. Like classrooms, it should be flexible in arrangement.

Figure 2.9. Diagram of critical spatial relationships in design



1. Kindergarten common area
2. Classroom
3. Project area
4. Storytelling area
5. Main group activity area
6. Quiet room or workroom
7. Washroom
8. Coatroom/vestibule
9. Outdoor study area
10. Covered play area
11. Outdoor play area
12. School common area

Source: Author.

- *Outdoor play area.* An outdoor play area directly accessible from the indoor common area should provide 7.5–10 m^2 per student. It should be partially covered, secured, and separate from adjacent areas.

A sample organizational diagram based on relevant program criteria represents critical spatial relationships in the design (figure 2.9). This, too, can be modified and adapted to reflect specific program needs.

Conclusion

As we look ahead to future innovations in preschool and kindergarten design, we must bear in mind that there is still much to be learned from the experience of the past. Educators, school planners, and architects must work together to better understand the legacy of modern school design and the ways in which critical relationships between architecture and education have been addressed to create inspiring places for learning. This is especially true at the preschool and kindergarten levels, where diverse and varied activities basic to the educational program should determine the design of the learning environment. Here, the underlying design themes most relevant are those that: promote community use, foster a sense of *school identity*, support a *variety of learning activities*, enhance *flexibility and adaptability*, facilitate *social interaction*, and improve the overall *quality of the learning environment*. The study of exemplary preschool and kindergarten environments from the past validates these themes and the design features associated with them. As architectural precedent, these schools are essential for developing program criteria that will ultimately inform and shape innovative learning environments in the future.

PART 2
Elementary School Designs

3

The Design of Elementary Schools

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A 21st-century elementary school is a complex system of environments that may have to address a wide variety of educational, social, recreational, environmental, and community needs. While each of these categories could be the subject of a separate article, I will use this chapter to offer ideas and references on all of them. Specifically, I will discuss the following topics:

- Creating a child-scaled environment
- Fostering flexible classrooms
- Extending learning beyond the classroom
- Employing subtle security
- Engaging the community
- Establishing a civic presence.

Creating a child-scaled environment

Elementary school may be the first institution that a child encounters independently of his or her family. Depending on the size of the school, this can be a psychologically daunting transition for even the most gregarious three-, four-, or five-year-old. One design goal should therefore be to ease the child's transition into an unfamiliar setting and thus foster a cohesive community of lifelong learners.

One strategy for accomplishing this goal is to reduce the perception, and perhaps the reality, of the school as a monolithic, uninviting structure and institution. Creating an environment that is closer in scale to familiar residential environments can help. Metaphors of houses, neighborhoods, villages, and public spaces drawn from neighborhood and urban design can help create an environment that successfully and progressively scales up from the individual to the larger learning community.

While it is not necessary for the architect to render these metaphors literally, they establish a small-scale home base for the students where teachers and their classes can build strong relationships. As we organize the school beyond the classroom, several classrooms ("houses") can be clustered into "neighborhoods." Depending on the pedagogy of the school, such neighborhoods may be organized by grade level or may house multiage groups. Neighborhoods can then come together into a "learning village."

Like our own towns and cities, the connective tissue between these units should be conceived of as productive public places—streets and plazas—rather than as a mere space for circulation. In a North American school, circulation may account for more than 25 percent of the building. Designing that space not only for movement but also for learning activates the entire building and further diminishes the likelihood that the building will feel like an intimidating institution to a young student.

Our metaphorical houses can also have "porches" onto public spaces, where color and display can establish the identity of the class learning within. Benches, tables, and chairs outside the classroom can extend learning into the public spaces of the building so that circulation may also afford a learning opportunity. Ultimately, the entire school community may gather in the "heart of the school," a town square or plaza that organizes the entire building and houses informal school gatherings and community events.[1]

Fostering flexible classrooms

Certainly among the most critical elements of an elementary school is the design of the formal learning space, typically the classroom. Many things need to be considered in the design of this environment if it is to provide an adaptable and appropriate setting for learning. Chief among these considerations are color, light, space, furniture, technology, display, and acoustics (figure 3.1).[2]

1. For further information on the design of corridors, lobbies, common areas, and other "nonprogram" spaces that create opportunities for learning and positive social interaction, and on the design of safe and observable spaces, see O'Donnell (2007: 20–23).

2. This section is based upon the author's forthcoming article on classroom design for the National Clearinghouse for Educational Facilities (www.ncef.org).

Photo: © Joseph Romeo. Courtesy Perkins Eastman | EE&K.

Figure 3.1. Stoddert Elementary, Washington, D.C. Color, light, space, furniture, technology, display, and acoustics combine to create an environment conducive for learning

Space

The construction cost of classroom square footage is easy to assess, but the impact of that space on educational outcomes is harder to determine unless one understands how students and teachers really use space. For example, in a comparison of large and small prekindergarten classrooms—including two larger Reggio Emilia–inspired classrooms of 940 square feet (87 square meters, m^2) and several smaller classrooms under 700 square feet (65 m^2)—it became evident that the smaller classrooms could not accommodate the diverse activities that the larger classrooms could. Likewise, the project-based Reggio pedagogy was better supported by the larger rooms in which student projects could be developed over a period of days without having to be moved or dismantled (figure 3.2). Every space in the smaller classrooms needed to be used for several purposes throughout the day, so children in these classrooms could not create the same long-term projects as those in the larger classrooms.

It becomes increasingly necessary to design spaces for less density as educational delivery—including project-based learning—is differentiated for older children engaged in individual, small-group, and large-group work in the same setting. Such spaces can range from a minimum of 30 square feet (2.79 m^2) per student to more flexible and adaptable highs of 45 to 50 square feet (4.18 to 4.65 m^2).

Furniture

Furniture is one of the most misunderstood and complicated topics in school design, one that becomes ever more complicated as the use of educational technology expands throughout a school. While the stature of students in the same class can vary dramatically, most furniture specified for schools is, for budgetary reasons, of one size and not adjustable. Some studies have found that, ergonomically, school furniture accommodates only 10 percent of students; the other 90 percent sit in chairs and at tables that are too high or too low. This incongruence can create ergonomic problems ranging from poor posture and strained backs to carpel tunnel syndrome.

Photo: © Joseph Romeo. Courtesy Perkins Eastman | EE&K.

Figure 3.2. Activity centers in a Reggio Emilia–inspired classroom

Ideally, adjustable-height desks and seats would accommodate the varied physical size of students and provide for appropriate ergonomic postures. Dieter Breithecker (2009) has argued that since children sit 10 hours a day on average, school furniture should also accommodate their developmental need to move—to shift position, rock, rotate, and roll. He suggests that these kinds of movements are critical to intellectual growth because they stimulate circulation and enhance attention and concentration.[3]

Bookshelves, cubbies, and other furniture also play an important role in organizing space in the elementary classroom, helping to create distinct "activity centers." Flexibility in the classroom is fostered by enabling the teacher and students to quickly reconfigure a room to suit a range of activities. Beginning with the youngest students, classroom furniture should enable the creation of a diversity of activity centers, possibly including science and art, block areas, dramatic play areas, writing centers, and places for the entire class to gather.

While younger children often have more opportunities to move about and shift their posture, owing to the less formalized structure of early education, as children grow older they often sit for longer periods in chairs and at tables. Even as emerging pedagogies promote more activity, furniture for older children should allow for rapid reconfiguration, enabling work arrangements that foster individual, small-group, or large-group activities. Students should be provided with opportunities to change posture throughout the day, including standing or reclining on soft seating, regardless of age.

Acoustics

The ability to hear and be heard is one of the most critical elements of a successful learning environment, especially for children who have not yet learned to read or who are learning a second language. To ensure an appropriate "signal-to-noise ratio"—meaning that the teacher, other students, and various media can be heard—both background noise and reverberation must be adequately controlled.

The American National Standards Institute (ANSI) has published standards (ANSI S12.60-2010) that define the maximum desirable background-noise levels in core teaching environments such as classrooms and laboratories at 35 dBA, with a reverberation time of 0.6 to 0.7 seconds. Achieving or exceeding these targets requires attention to several systems, including heating, ventilation, and air conditioning as well as walls, windows, doors, ceilings, and floors. Performance criteria related to "sound transmission class" are also specified to ensure appropriate separation from adjacent sources of noise. Exterior noise is often the most difficult to control and is most challenging at urban sites, requiring greater performance from window assemblies in particular.

3. For more on the design of furniture appropriate for children's developmental needs, see Breithecker (2009).

Proper acoustics within and between rooms will likely become even more critical over time as the use of audiovisual equipment with multimedia capabilities—such as interactive whiteboards—continues to proliferate alongside the learning pedagogies that employ them.

Color

We know from published reports of experimentation that certain colors can cause physiological changes in blood pressure. For instance, red is often associated with heightened blood pressure, whereas blue is associated with decreased blood pressure. These heightened or dampened states of excitation are often assumed to be more or less appropriate for learning. But while blood pressure is readily quantifiable, many of these studies do not provide sufficient information to derive a direction for design because they provide no correlation between blood pressure and performance or learning outcomes. Also, response to color is culturally variable.

In contrast to these more generalized assumptions, several studies have suggested that specific colors may have an effect on the performance of specific types of tasks. In a study published in the journal Science (Mehta and Zhu 2009), the authors indicate that different colors may influence different levels of attention: red influences higher performance on detail-oriented tasks; blue on creative tasks. While this study was based on the background color of computer screens being used on specific tasks, similar studies have gauged performance in office settings of different colors.

Rather than focusing on performance differentials related to specific colors, Mahnke (1996) suggests that better design results may be obtained by focusing on the use of color to reduce glare and eye strain. For example, Nuhfer (undated) recommends accents of a "different complementary or darker hue." He argues that such color, if located on a presentation wall, will help reduce eye strain as students shift their focus from their desk to the presentation. Likewise, others suggest that the application of one color to three walls and another color to a single wall will reduce visual monotony in the environment.

Lighting

In addition to acoustics, appropriate lighting is one of the most critical performance attributes of the learning environment. Strongly related to both color and energy performance, lighting in a 21st-century school draws upon natural and electric light sources and requires special attention to the various activities (and surfaces) being lit, the use of technology, orientation, and time of year.

With activities ranging from napping to detailed project-based work, and learning media ranging from finger paint to digital audiovisual displays, lighting in an elementary school needs to be adjustable to the task at hand. Considering the diversity of activity that can occur simultaneously, lighting may also need to vary across a room. Built-in shelves where plants can grow in natural window light, for example, may be found alongside glare-free areas better suited to the use of technology.

The challenge is to provide glare-free natural light supplemented by switchable and dimmable electric lighting (figure 3.3). Tall windows with shades and, depending upon the orientation, light shelves can help provide glare-free natural light deep into a classroom. Direct-indirect electric lighting can supplement the daylight available by illuminating the ceiling and providing sufficient "down light" to enliven the space, provide for good color and spatial rendition, and ensure visual comfort. Task lighting may also complement ceiling-mounted fixtures. An integrated design approach should assess the reflectance of the colors and materials in the room in concert with the lighting design, reducing the potential for excessive contrast and glare.[4]

Technology

Kindles, iPhones, iPads, YouTube, Facebook, Twitter, cloud computing, converging media, social networking, asynchronous learning—technology is a fast-moving target. Dr. Michael Rich, director of the Center on Media and Child Health at the Children's Hospital in Boston, says that with the ubiquity of media use in the United States, it is time to stop arguing over whether it is good or bad and accept it as part of a child's environment (*New York Times*, January 20, 2010). The Public Broadcasting System (Grunwald and Associates 2009) has emphasized the increasing comfort and use of digital media by teachers in the United States; it also indicated the growing, but still limited, use of media by students while in school. A Kaiser Family Foundation report (2010) provided a counterpoint to the PBS findings by exploring the pervasive recreational use of media by children outside of school in the United States.

Technological devices will continue to become smaller, more mobile, and more widespread. The rate of development of educational technology will also continue to outpace the funds available to adapt buildings to house these new technologies and take advantage of new learning opportunities.[5]

Accordingly, we need to design flexible environments that can change quickly without requiring renovation. Dedicated computer labs will become less useful as mobile technologies—such as laptops, iPads, smart phones, and "clickers"—enable students and teachers to bring technology to the task, rather than the task to the lab. Computer labs, meanwhile, should be designed so as to be easily adaptable to other productive uses over time. Classrooms need to include furniture that accommodates the use of laptops and

4. For more formation on lighting design, see Perkins (2010).
5. For more on the rate of change of technology versus the ability of architecture to adapt, see Ehrenkrantz (1999).

Photo: Courtesy Perkins Eastman | EE&K.

Figure 3.3. Stoddert Elementary, Washington, D.C. Pervasive natural light and plentiful display

other mobile technologies as they emerge. Mobile technologies with wireless access will provide the ability to connect across the campus, making it possible to use technology to write a report in the classroom, make a presentation in the library, or catalog insects in the school garden.

Display

Another useful metaphor for classroom design is to imagine the classroom as a stage for learning. As a stage enables varied sets to be constructed, so every surface of the classroom can be engaged in the learning process, particularly the walls and even the ceiling and floor. Personalization of the learning environment through two- and three-dimensional displays reinforces the learning process and communicates the values of the learning community. Frequently, however, numerous door openings, storage units, heating and air conditioning equipment, electrical devices, grills, wainscots, and, sometimes, even too many windows reduce the amount of available wall space. Classroom designs should ensure that wall surfaces, particularly at the scale of the children, are as unencumbered as possible. The ceiling is also an opportunity for suspending artwork or curtains from a grid, or even—with proper structural design—for creating kinetic physics experiments.

Extending learning beyond the classroom

Learning is not confined to the classroom. Because informal and formal learning can and should occur throughout the campus, a school can provide opportunities for students to grow intellectually, socially, and emotionally through appropriate design (see footnote 1). Accordingly, every square foot of the campus should be considered a setting for learning. As noted above, circulation in some schools may comprise more than 25 percent of the building. As students move through the school, displays can engage their imaginations, seating areas can provide a place to linger with a friend for a moment, and interactions with faculty can reinforce classroom activity.

Circulation space can also be reconceived as an active extension of the classroom, providing breakout space for small group work, reading groups, and projects. Active use of circulation space is fostered by transparency between the space adjacent to the classroom and the classroom, enabling the faculty to observe and engage. Optimizing the campus extends outdoors as well. Even in colder latitudes, microclimates can be created—for example, a courtyard that invites use in all seasons. Site design amenities such as gardens, amphitheaters, loggias, and plazas offer still more possibilities.

Photo: © Joseph Romeo. Courtesy Perkins Eastman | EE&K.

Figure 3.4. Stoddert Elementary, Washington, D.C. Transparency, open doors, and subtle security

Employing subtle security

All schools should be oases of safety. Creating a learning environment where students can learn free of safety-related stress requires consideration of at least two commonly discussed threats: intruders and bullies. Often a response to the first is to turn toward technology—video cameras, magnetometers, x-ray machines—and then to create a wall around the campus. These are reactive approaches that may be necessary in some circumstances, but school design should also take advantage of more proactive strategies that are derived from and foster a strong learning community.

Building on the idea that a good learning community is generated through good communication, applying the principles of openness, transparency, and engagement can create a more subtly secure environment that can transform a school from an institutional and somewhat threatening setting to an inviting and safe place to learn. Taking a lesson from Oscar Newman's "defensible space" design strategies, one of the keys is to have many "eyes on the street." Transparency throughout and around the school enables people to see and be seen.

Intruders can be frustrated by limited access. Often, older schools have many points of entry, providing opportunities for unwanted guests, not to mention confusing visitors. A single, clearly indicated front door flanked by windows to the school's administrative offices can ensure that school staff actively engage all arriving visitors (figure 3.4). The reception area can be designed to be open and welcoming, making immediate contact with arriving visitors easy. In some designs, visitors are routed directly into a main office.

Bullying occurs in spaces where adults are not likely to see it happen, often in stairways, corridors, cafeterias, and playgrounds. A school's architecture can help by featuring spaces that encourage greater interaction among adults and students throughout the campus, reducing the exploits of bullies. One strategy is to distribute administrators throughout the campus. With offices, copy rooms, and faculty workrooms arrayed across campus, adults are more likely to be moving through all areas of the school, engaging the students and modeling appropriate behavior. For example, a faculty workroom might be located to overlook a playground or a counselor's office might be placed on the second floor, intermingled with classrooms.

Another way to address bullying is to use transparency to reduce those areas where students can be out of sight. For instance, glazing between program spaces and circulation encourages visual engagement and communication, reducing inappropriate behavior. Likewise, glazing in stairways allows people to see and be seen while having the added benefit of bringing natural light into an often foreboding and dark space.

Engaging the community

Public investment in school construction is significant, and schools are often the most widely accessible facilities that a government constructs for its citizens. Because of their convenience and the need to maximize resources, schools can be conceived as community centers that serve not only school-age children but also preschool children, adults, and seniors. By offering recreation, health care, meeting spaces, and continuing education opportunities, an elementary school can increase the utilization of a major investment in facilities and provide services that otherwise might not be available in many communities.

When inviting the community into a school, special attention should be paid when zoning the building to allow staff to limit public access to specifically defined areas. For example, the gym, library, cafeteria, and multipurpose rooms could be zoned for use as community centers after school hours, while the portion of the school that houses classrooms is closed off. Preventing the public from wandering the halls makes the facility more secure and easier to keep clean.

When programming an elementary school, community use may also influence the size, types, and configuration of the spaces and furniture provided. For example, a gym sized strictly for young children may be uncomfortably small for adults to use recreationally over the weekend. A health clinic or a preschool may have its own front door for convenience and to control access to the larger school during the day. A multipurpose room may have adjustable furniture that accommodates adults.

Establishing a civic presence

Finally, when designing a school, it is important to consider the symbolic role of the school in the community. How does it represent—to students, staff, and passersby—the value that the community places on education? What does it suggest about the history and the future of the community? There is no singular answer to these questions, and engaging designs have been made to address all of them—designs that reflect cultural identity through the use of color, permanence through the use of masonry, sustainability through visible photovoltaics, and openness through the use of glass, for example.

The best buildings also create great places around them. Entry plazas and landscapes contribute to the first and lasting impression of a school and create transitional zones where the school and the community can come together (figure 3.5).

New and existing elementary schools in the 21st century

The design of 21st-century elementary schools requires attention to myriad interrelated issues—among them pedagogy and technology, cognition and perception, cultural goals and values, budgets, and demographics. Our overarching need is to ensure the future of our communities by educating our children in facilities that are welcoming, safe, and supportive. While the ideas put forth in this chapter may seem to imply a need for new

Figure 3.5. Stoddert Elementary, Washington, D.C. The school grounds welcome the community

Photo: © Joseph Romeo. Courtesy Perkins Eastman | EE&K.

construction, they apply equally to the adaptive use of existing school buildings and campuses. Jurisdictions should strategically evaluate their entire inventory of elementary schools, planning new ones that will be successful today and in the future while also assuring that our existing campuses continue to adapt and serve their communities.[6]

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6. For more information on the ability of existing schools to house 21st-century programs, see O'Donnell (2010).

4

Argentina's National 700 Schools Program: Complexity, Diversity, and Scale

Ricardo Santocono, Architect, and Andrea Bardone, Architect

Human society exists within a spatial context. We construct space tangibly as well as through knowledge: social, sacred, and economic spaces, cyberspace, etc. And just as life's activities lead us to construct spaces, the spaces we conceive or create affect our daily lives in multiple ways. They stimulate, restrict, and organize our individual actions and social relationships. This relationship between humans, their use of space, and their identity establishes paradigms for understanding human interaction, which schools can amplify. Therefore, in focusing our attention on educational space, we hope to contribute to an understanding of communication in schools, social and power relationships, and the transformative power of space and architecture.

> *Every child goes to school in a building that looks like a duplicating-machine replacement-parts wholesale distribution warehouse.*
>
> Tom Wolfe, *From Bauhaus to Our House*

School as we know it is disappearing, and it is becoming increasingly difficult to determine its boundaries. We must compile a new list of needs to define structures that respond to the new functions of educational spaces. We must reflect on which questions need asking. Is it necessary to homogenize in order to educate? Is it possible to create a pedagogy completely independent of vigilance, control, and regulation? What mechanisms will disappear and what will replace them? Where does education begin and where does it end? What language will define the millennium?

According to current educational practices, schools seem to require that students conform to certain spatial prerequisites, as if these were conditions for learning in an educational setting. Yet educability largely depends on the conditions of the educational space. In other words, the possibility of learning is, in the words of Baquero (2003), *an attribute of the situation*. We must therefore ask: Can architecture improve the situation? What must we take into account?

Background

Most Argentine schools do not reflect the tendency towards change seen in the rest of society. The learning process has changed, the students have changed, but school buildings have remained the same. Unlike other spaces, schools are characterized by their permanence. Despite the profusion of virtual, fluid, and superficial spaces, the school has retained its colors, trappings and symbology over time.

Each new situation requires a new architecture.
Jean Nouvel

But primary education, the oldest and most immutable level, underwent curricular reforms in the late twentieth century that impacted its spatial needs. Today, at the end of the first decade of the twenty-first century, it is facing new curricular demands that we, as architects and planners, must respond to. Beginning with the National Education Law of 2006, primary school education was made to last six years, with strong references made to extending classes to a full day.

The National Education Law of the mid-1990s reduced primary school from seven to six years while extending general basic education to nine. The length of mandatory education was also increased to ten years (the last year of preschool plus the nine years of general basic education) which had lasting consequences for school infrastructure. Every available space was converted into classrooms to accommodate the added grades. Hallways, multipurpose rooms separated by room dividers or curtains, music rooms, libraries, cafeterias—any space could be converted into a classroom. Although these changes were intended as temporary, in many cases they were never reversed. Meanwhile, expansions, reforms, and additions led to the disappearance of patios, terraces, playgrounds, and fields.

Argentina's 1998 National Census of School Infrastructure (*Censo Nacional de Infraestructura Escolar*, CENIE) revealed a total of 34,721 school buildings, including 27,946 for public schools and 6,775 belonging to private schools. Nevertheless, due to the persistent rise in demand and the real and physical impossibility of meeting it through existing structures, construction programs since the early 2000s have increasingly provided new infrastructure.

The National 700 Schools Program

In 2003, the Ministry of Education created the Program for Improvements in the Education System (*Programa de Mejoramiento del Sistema Educativo*, PROMSE), designed to support provinces in improving quality, fairness, and efficiency in the education system and strengthening teaching at all three levels (preschool, primary, and secondary), particularly among the most vulnerable sectors of society. In this context, the Ministry of Federal Planning, Public Investment, and Services established the National 700 Schools Program.

The general aims of the program were to respond to projections of unmet building infrastructure needs in public schools (preschool, primary, and secondary) within a five-year timeframe and to replace existing buildings that presented a safety risk or did not have the functionality necessary to assure quality education.

The program's specific objectives were to:

- Increase enrollment
- Decrease drop-outs, particularly in groups with unmet basic needs (UBN)
- Decrease grade repetition and the incidence of over-age students
- Improve academic performance in language, mathematics, and social and natural sciences
- Improve cost efficiency.

The program reached 24 jurisdictions throughout the country, including 808 schools in 710 buildings totaling 1,024,748.47 m^2. It benefited more than 282,000 students. This was immediately followed by the More Schools Program which was projected, by the end of 2010, to affect 510 schools in 451 buildings, totaling 466,662.39 m^2 and aiding 154,029 students.

Currently, the More Schools Program II has been approved, projecting 410 schools by the end of 2011 totaling 369,466 m^2 and benefiting 102,132 students. By the end of 2012, these numbers will undoubtedly reach 1,728 new schools comprising 1,860,877 m^2, affecting 538,291 students. These figures are unprecedented for any program or school infrastructure policy in our country.

Lessons learned

We are currently faced with redefining the new program, reaching consensus on standards and criteria that will result in a better and more efficient distribution of resources. The construction of learning spaces requires interaction between different fields of expertise, wherein the participation of all parties is vital.

An interdisciplinary team must evaluate the needs and social relationships of those involved, including the specificities of each formative stage, considering the requirements of the education laws.

Our challenge—if we want to address future changes—is to create school buildings that incorporate high-quality spaces that foster learning and teaching and are both functional and flexible. They must meet the demands of curricular changes, new information and communication technologies, and new forms of collective management.

The architect's task is to understand the complexity of the process, beginning with the formulation of state policies, taking into account community needs, and incorporating regional cultural dimensions. Beginning with the right of children and youth to receive a suitable education, the architect must overcome technical and budgetary limitations to finally reach the moment of design.

The concept of "flexibility," although historically absent in public school buildings, has become especially relevant today. The word envisions not something vague or indeterminate, but rather a space that, while clearly structured, allows for changes, modifications, and variations in accordance with all needs.

We have reassessed some of the variables that affect the social and environmental impact of new buildings, as well as aspects of community "ownership" of the buildings, the rediscovery of public schools as common goods, and conservation and maintenance plans. All of these variables represent aspects that must inevitably be considered in the mid- and long-term development of infrastructure.

Pending issues

We propose a series of actions to achieve a more efficient and relevant implementation of school building construction policies. Far from being prescriptive, these are recommendations or invitations for discussion and reflection:

- Define a conceptual framework to establish the institutional identity of the school building as part of an investment in new school infrastructure on a national, regional, and local scale. Given the building's particular context, for example, rural or urban, provisions can then be made for buildings to meet the community's pedagogical, educational social, technical, and operational needs.
- Analyze the determinant factors of the proposals (that is, the intended educational level, climate, terrain, social organization, construction techniques and available materials, the degree of workforce specialization, etc.) in order to propose designs adapted to the circumstances, both rationally and economically.
- Establish project standards and criteria by revising those historically applied to the development of school infrastructure.

- Define quantitative and qualitative guidelines for the spatial requirements for different levels and teaching and learning methods, paying particular attention to primary and middle school needs.
- Systematize constructive solutions to optimize quality standards and minimizing corrective maintenance needs by following the standards.
- Develop proposals that resolve the relationship between initial and maintenance costs in line with the goal of maximizing available resources and assuring their equitable distribution.
- Value all types of innovation including modular approaches and new materials and building techniques that reduce costs and time involved.
- As Cabanellas and Eslava state (2005: 172, 21), "architecture must originate in pedagogical thinking and pedagogy must take into account the life experience of the architectural space..., accepting the challenge of a commitment to forge the reality we wish to inhabit."
- Therefore, whatever the context, be it rural or urban, the challenge is to create an architecture that originates in pedagogical thinking while taking into account the multiple functions of twenty-first century schools.

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PART 3
Secondary School Designs

5

School Infrastructure and Education Reform in Chile

Jadille Baza, Head of Architecture, School Infrastructure Department,
Ministry of Education, Chile

In analyzing educational spaces at different levels, it is clear that space is generally being used and managed at the primary and secondary levels in a rather traditional way. This has an impact on the design of these spaces, which continue to preserve the same characteristics over time despite new pedagogical requirements, technological advances, and innovations in working methodologies.

Preschool activity rooms are based on learning corners. Higher education students rotate between subject-specific areas. But at the primary and secondary levels, classrooms retain characteristics that promote face-to-face instruction and in which the students are seated one behind the other, preventing the current dynamic of interactive learning in which students also learn from their peers. In this sense, we can observe a significant disjunction between the spaces dedicated to the various levels of education. In moving from one to the other, students are subjected to radical changes.

But it is not enough to simply have well-designed educational spaces with respect to projected needs. Their management and use must also be taken into account.

In the mid-twentieth century, Chile, along with other countries in the region, was faced with the challenge of increasing educational coverage so that all students would receive eight years of basic mandatory education. As a result, there was a rise in secondary school enrollment rates.

In order to meet this demand, a school building extension plan was enacted. It was supervised and carried out by the Corporation for the Construction of School Buildings (SCEE, *Sociedad Constructora de Establecimientos Educacionales*), a technical and executing entity that oversaw the construction of educational facilities in the country for more than 50 years. The architecture applied was based on a model construction system in line with a unified national curriculum.

Since the 1990s, as a result of educational reforms, Chile has sought to improve quality, participation, and fairness in the educational process. The goal for infrastructure has been to arrive at an architecture that motivates and encourages learning while also responding to the new requirements and teaching methods introduced during the educational reforms of the 1990s. These reforms proposed five lines of action:

- Key objectives and minimum curricular content
- Teacher development
- Initial teacher training
- Full school day
- 12 years of compulsory education.

The extension of the school day had the greatest impact on infrastructure, which in some cases had to double capacity as schools went from double or triple shifts to a full school day; however, each aspect of the reforms brought with it a need to rethink educational spaces. The goal was to contribute to and facilitate the changes included in the reform. Among these were the shift from a unified curriculum to one based on fundamental objectives and from unified content to institution-based educational projects designed in each school. This change led to a "case-by-case" type of architecture that took each local situation into account. Teacher training and development also involved adopting new methodologies and joint work practices among both principals and teachers.

In general, the idea is to generate more and better educational spaces that facilitate the learning process. A new standard emerges: a dialogue between the architect and the educational community represented by—at the very least—principals and teachers. In contrast to taking possession of an unfamiliar building, the process becomes one of managing and using a school that these representatives have had a hand in conceiving and designing, relating the educational project to the available space and its characteristics. This not only improves architectural responses, but also provides an incentive for the educational community and reinforces a sense of belonging as well as a concern for the care and maintenance of the infrastructure.

Along with the challenges of an architecture that must take into account the socio-cultural realities of its particular location, all of these factors allow for a transition from one-size-fits-all designs to case-by-case architecture.

In moving from an architecture based on generic models to one based on case-by-case designs, the Ministry of Education since 1997 has pursued a project in partnership with UNESCO. Entitled "Chilean Education Reform: Optimizing Investment in Education Infrastructure" (*Reforma Educacional Chilena: Optimización de la Inversión en Infraestructura Educacional*), the project has produced several studies culminating in handbooks for the design of educational spaces and school furnishings. It also supported experimental pilot projects, an exchange of regional experiences throughout the country, and assistance from international specialists through consultations, seminars, and workshops, several of which were open to other countries in the region.

A variety of participants' perceptions of educational spaces were considered, including those of students in free-form art contests. Since 1999, a call for proposals has been sent to schools of architecture in Chile's universities, encouraging them to work jointly with educational authorities to design schools. Likewise, national architecture competitions have been held to motivate architects throughout the country to participate in the search for the best school spaces (figures 5.1 and 5.2). The goal was to improve the quality of education by promoting cultural change based on an understanding of local identity and valuing educational heritage.

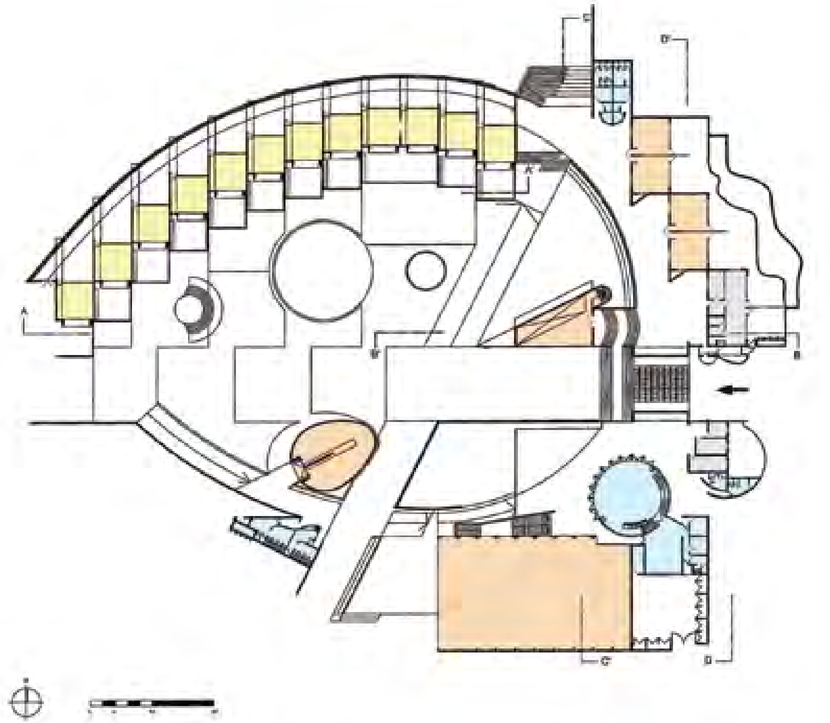

Photo credit: UNESCO–MINEDUC Project

Figure 5.1. Winning design for Aldea Educativa Rapa Nui School on Easter Island

Figure 5.2. Competition for architecture students, ChilEduca

Another aspect of the reforms that affected architecture was to commission works of art for new and existing schools, fulfilling the terms of Bill 17.326, *Comisión Nemesio Antúnez*, which requires buildings and public spaces to be enhanced with works of art (figure 5.3).

School furnishings were analyzed and studied with the aim of improving their quality, adapting them to meet the educational and ergonomic requirements of each step in student development. Based on the study, a handbook was created for the acquisition of school furnishings.

Considering the large investments required for countries to maintain existing school property, let alone create new educational institutions, spaces should be flexible and multipurpose whenever designs and time allow. They must also be consistent with the geography and culture of their surroundings and take into account the dynamics of the educational process and the incorporation of technology that is accelerating change, all in a setting comfortable for learning.

Spaces must be safe and appropriate to facilitate and promote a good school environment. Particularly at the high school level, we must take care that students have the opportunity to experience what they are learning in the classroom. Educational spaces should foster innovation and updated pedagogical practices such as teamwork and the rotation of students among subject-specific classrooms.

However, with students spending more time in school owing to the extended school day, there is a demand for leisure, interaction, recreation, and rest spaces, organized in an age-appropriate fashion (figures 5.4 and 5.5). The accompanying photos show several buildings taking this into account and being used for recreational, cultural, and outdoor activities.

These characteristics allow schools to be opened up for communities to make use of their infrastructure (e.g., for continuing education), and for high schools to make use of other public and private spaces (in dual education, for instance, which incorporates specialized practical workshops into the high school curriculum).

Figure 5.3. Art work at educational institutions

In general, there is a demand for architecture that:

- Facilitates the educational process
- Reduces regional and local inequalities and disparities between urban and rural areas
- Projects usage over the duration of the buildings' useful life ("working with the future").

By sticking to their educational objectives, the reforms have fostered renovation and construction of many new and dynamic secondary schools throughout Chile. Bearing in mind that education is the primary catalyst for change, construction was guided by the principle that school spaces, as the setting for knowledge production, have a direct impact on learning.

Figure 5.4. Schools should provide space for interaction, recreation, and rest

Figure 5.5. Longer school days demand adequate space and time for leisure and recreation

The reforms of 2010, related to the reconstruction of educational institutions affected by the February 27 earthquake in the central region of the country, have opened up new opportunities for the improvement of educational spaces that provide a quality education, particularly with respect infrastructure standards, efficient energy use, and private sector financing models.

6

Secondary School Design in Italy

Lucas Fornari, Architect, Studio Altieri S.p.A.

The Italian public education system consists of 9 million people, including 8 million students and 1 million faculty and staff. They are distributed throughout approximately 45,000 buildings, more than two-thirds of which are in critical habitability condition due to age, safety issues, or inadequate size.

Some parameters of the Italian system

The state, via school planning programs, is financing construction of new buildings and renovation of existing ones. Municipal or provincial bodies evaluate the needs of the school population in their area forward requests for new infrastructure to the Ministry of Education. The bid that best responds to pre-established evaluation criteria is selected through a public bidding process. In this way, the project that corresponds most closely to public demand is chosen.

The basic elements of every school project are the classroom, its configuration, its characteristics, and its potential for aggregation. Primary school students need a classroom suitable for a variety of pedagogical activities, whereas students in secondary school tend to move among specialized classrooms like labs and workshops. This difference demonstrates that not all educational spaces are equal, nor should they all have the same characteristics.

According to the Organization for Economic Cooperation and Development (OECD), there should be a standard student-to-teacher ratio of 21 to 1. This guideline cannot be applied in Italy, however, because of the high level of territorial fragmentation, which makes a uniform distribution of the student body impossible. As a result, the Italian standard (DM December 18, 1975) is based on a 25 student per teacher ratio. Even so, in Italy, classrooms tend to be oversized because of problems with the management of the advanced teaching staff. Statistically, public high schools see up to 15 percent attrition in the first year as students migrate to other institutes or drop out.

A Ministry of Education decree establishes minimum parameters for the size of high schools based on the number of sections and the various orientations offered by the schools. The ministry has established values from 6.65 to 9.7 m^2 per student for the overall gross surface area of high school structures.

Other functional units relevant to secondary education are essential in completing the educational setting. Whereas in primary schools didactic activities typically take place within a single classroom, which becomes a multifunctional space for children, in high schools the students move among several classrooms dedicated to specific activities, such as language and science labs or practical workshops associated with technical schools that have a consistent local demand for labor. Thus the labs take on a very important role and should be designed with the proper level of flexibility to permit future adaptation of the space in case of a change in the school's needs.

Schools buildings must also take the sociocultural diversity of the students into account. For instance, more than 50 percent of students in Italy do not want to participate in Catholic religious education and instead choose a secular option, requiring a dedicated space for half the students to engage in alternative activities during certain hours of the school day. The Italian system also includes students with different skills—as is typical throughout Europe. Ethnic and cultural minorities come from different parts of the world and need to learn Italian alongside their other studies. The Ministry of Education favors the integration of different cultures, ethnicities, and diverse groups in the classroom, as do teachers and other staff. Experience shows that there are benefits to separate students in specific cases (e.g., specialization) and with respect to specific demands; the schools meet those needs through smaller support classrooms.

Studio Altieri projects

With more than a hundred years of tradition and experience in architecture and engineering work, Studio Altieri is one of the most specialized studios operating in Italy, Eastern Europe, and the Middle East. The studio focuses on research and development for public interest education and healthcare projects, integrating architecture and engineering with other specialized disciplines. During the Symposium organized by the IDB in Santiago, Chile, on October 26-27, 2010, Studio Altieri showcased its experience with examples of Italian high school designs.

The following schools are examples of Studio Altieri projects:

Montecchio Precalcino Secondary School, Vicenza Province, Veneto

This is a 600-student secondary school. The design identifies the following functional modules: classrooms, labs, special classrooms, a library, and administrative areas. The structural layout is based on an 8m x 8m module and allows for up to 27 students per class.

The classroom design takes several factors into account:

- Natural light—the most important factor:
  - Enhanced student concentration and activity while conserving energy
  - Improved visual comfort
  - Smooth, light-colored surfaces and sound-damping, resilient flooring
  - 50–80 percent reduction in energy consumption
  - Control over reflected sunlight
  - Favorable positioning of the building
  - Ceiling panels designed for good light distribution and acoustics
  - Shades to limit uncomfortable glare
  - Glass: Reduction in the sunlight luminance factor, luminance transmission, and color rendering
- Acoustics: minimizing interior reverberation
- Color: glare reduction and contrasting floor colors.

The architecture of Montecchio Precalcino Secondary School is based on clean lines with the goal of integrating the school into its surroundings. The horizontal model, which allows for semi-covered spaces, favors transition from semi-covered interior spaces to exterior spaces. The common areas are simple and built of durable, easy-to-maintain materials.

"A Ceccato" General Contractors' Technical Institute, Thiene, Vicenza Province, Veneto

This technical school was designed and planned around a central atrium that serves as a multipurpose space. Classrooms were designed to be versatile to accommodate atypical uses such as a diversity of students at different stages in their training while also allowing space for integrating computers. The classrooms' 10m x 10m structural module allows for flexible use, including space for small experiments to be carried out in class.

The circulation of natural air inside the classroom is important, as regular air replacement maintains a good level of air quality, which is an essential factor in encouraging good schoolwork by students. The technical school's classrooms were designed with cross-ventilation in mind, with dedicated air ducts in each classroom that use natural air currents to guarantee regular air replacement.

Biological Technical Institute, Pisa Province, Tuscany

This school accommodates almost 1,800 students. Studio Altieri concentrated the majority of the common areas at the front of the school. These include labs with space for alternative activities as well as a library, a key element in an educational facility that links several institutes. The library, which is open to the public, contains many books transferred from other institutes. The lecture and study rooms, which are very important, are organized around two central patios at the heart of the system. Studio Altieri concentrated the largest classrooms on the ground floor, including the main lecture hall used for seminars. The lecture hall, which is positioned at the entrance, is important because it is connected to the grounds and can be used by the community through a separate outside entrance.

The design of this school also takes advantage of natural light. The open north-facing facades are benefit from strong light while the south-facing facades, which are more exposed to sunlight, must be handled differently, insulating the interior spaces to diminish climate-control costs. In this case, ventilated facades and treated glass were used to control heat transfer.

Figure 6.1. Pontevico-Lombardy Superior School, Brescia Province, Lombardy

Pontevico-Lombardy Superior School, Brescia Province, Lombardy

This 600-student school, which occupies one ground floor and one subsurface floor, is organized into functional blocks connected around a common area containing the interior hallways (figure 6.1). The classrooms, administrative areas, library, labs, and teachers' room, all required by Italian regulations, are clustered together in independent sections with ample views of the surrounding gardens.

Another important functional unit is the gymnasium, which contributes to pedagogical development and the resolution of problems that the Ministry of Education, Universities, and Research (*Ministero dell'Istruzione, dell'Università e della Ricerca*, MIUR) confronts every year. Transporting students to off-campus sports facilities is one of the most significant causes of legal claims against the Ministry due to accidents during transport. Unfortunately, gymnasiums are usually the first thing to be sacrificed to incorporate higher priority educational spaces. Architects often insist on including gymnasiums in the first phase of their projects because these integrate school and community and promote sports activities.

Another functional unit is the common areas. Good-quality common spaces foster interpersonal relationships between students and teachers. Outdoor common areas create community spaces and stimulate relationships with the outside world and with nature.

Macro areas and macro topics related to sustainability:

- Management of water consumption: rainwater treatment; gray water treatment; water efficiency through recycling treatable water
- Geothermal energy: heating or cooling the building using energy from the earth; natural ventilation; radiant systems with underground water
- Green roofs: reduction of almost 70 percent in solar radiation received inside the building; thermal insulation; sound isolation
- Renewable energy sources: solar and photovoltaic panels.

Liceo Clásico Institute, Viterbo

In this school, functional blocks were built around a central courtyard with an integrated gymnasium/auditorium that is open to the community. The labs and workshops are designed with significant flexibility while the classrooms and administrative areas follow a more traditional configuration. The school's architecture is simple and has a classical appearance, using the typical colors of the Roman house and focusing on spacious atriums.

Figure 6.2. Green roofs at the Bellavitis Middle School

Bellavitis Middle School, Bassano del Grappa, Vicenza Province

Studio Altieri faced a number of difficulties in carrying out this project. A street bisects the school's campus, and the administration did not want to incorporate sports activities because they could not be fitted inside the school complex. However, the space was successfully restructured with the gymnasium, which can be converted into a multipurpose room, built on the far side of the street and integrated with the rest of the campus by a landscaped roof (figure 6.2).

The interior spaces were transformed into common spaces and reference points. This school consists of three large components: student recreation spaces, which can be used for informal performances; the entrance and lobby area; and the gymnasium. A landscaped thermal roof can be addedd to insulate the building, reduce energy costs, and reduce noise by almost 10 decibels.

Secondary School at Costabissara, Vicenza Province

In this school, we applied a variety of geothermal energy sources. The geothermal system pumps 15° ground water through a radiant floor system to cool the building in the summer and uses the radiant floor system to heat it in the winter, assisted by ventilation of the indoor patio and thermal gains from the glazed common areas. Relying on these climate-control methods is possible because the school is closed during the hottest months of the year.

In winter, a mixed radiant floor system and controlled air are used. The sun heats the common areas around the patio to 20°C. Required temperatures are obtained using a purified air system. In summer, 15°C groundwater is heated to obtain the desired temperatures. The radiant floor system uses 15°C groundwater to cool the entire building.

Table 6.1 compares traditional climate-control systems with the solution implemented here, showing the annual savings.

Table 6.1. Comparative table of energy performance

Data	Traditional solution	Sustainable solution
Heat Requirement (W)	264,900	47,000
Fuel	Natural gas	Geothermal/Electric
Annual Consumption	595,967.80 kWh/year	93,996.00 kWh/year
Cost of electricity/year	a50,004.00	a14,099.40
Savings/year		a35,904.60
Fossil fuels saved kWh/year		361,052.80

Conclusion

We suggest building less but building better. Buildings should be expandable and adaptable over the long term, in phases that accommodate the normal school cycle. Older buildings should be approached with an eye to preserving cultural and historical heritage while modifications are made to eliminate asbestos, protect against risks of fire and earthquakes, and comply with building codes and regulations.

PART 4

Dealing with Hurricanes and Earthquakes

7

Designing and Strengthening Educational Facilities to Withstand Earthquakes and Hurricanes

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Earthquakes and hurricanes are feared the world over, and for good reason. They can cause a tremendous amount of damage to buildings and structures, as well as injury and death to occupants and residents. Earthquakes hit with practically no warning, causing havoc in just a few seconds. Hurricanes are not as unpredictable as earthquakes, but they occur more frequently and sometimes affect larger areas. In September 2010 the United States Geological Survey (USGS) reported some 35 earthquake occurrences, in various parts of the world, with magnitudes exceeding 6.0 on the Richter scale. The most powerful of these was the 8.8-magnitude Chilean earthquake of February 27, 2010, since exceeded by the 9.0 quake that hit Japan on March 7, 2011. In the United States, 1,836 people were reported dead in 2005 from Hurricane Katrina, one of the five deadliest hurricanes in U.S. history, and the subsequent floods. Damages from Katrina were estimated at $81 billion.

The good news is that risks from earthquakes and hurricanes can be minimized by better planning and improved design and construction practices.

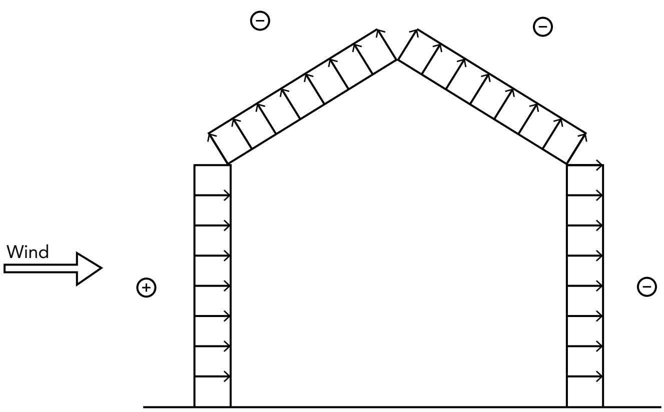
General effects of earthquakes and hurricanes on buildings

The earth's crust is composed of moving tectonic plates. These plates occasionally collide, building up the strain between them and provoking eruptions in the form of earthquakes. Shock waves spread through the soil, leading to ground-shaking tremors, or vibrations. Buildings subject to such motion suffer stress to their structures (supports). When structural elements are not properly designed to resist this stress, they may get damaged or collapse. Meanwhile, earthquakes can spur other events, such as soil liquefaction, landslides, and avalanches. Vibration is, however, the only effect generally considered in building codes, both because it is the most damaging effect and because it typically affects a large geographic area.

Hurricanes are tropical storms characterized by rotating winds of very high velocity that can cover a geographic area with a diameter of 500 miles (805 kilometers, km) or more. According to the Saffir/Simpson hurricane classification scale, hurricane wind speeds start at about 74 miles per hour (mph) (119 kilometers per hour, kmph). According to this scale, the highest category of hurricanes, rated 5, is characterized by maximum sustained winds of 155 mph (249 kmph) or more, and a storm surge of more than 18 feet (5.5 meters) above normal.

Hurricanes are normally accompanied by heavy rains that lead to flooding problems. During a hurricane, a building is subjected to extreme wind forces, various levels of flooding, storm surges, and battering by water and airborne debris. Wind forces acting on a building take the form of inward or positive pressure on windward walls (the side facing the wind) and negative pressure or suction on leeward walls (the downwind side). The negative pressure is generally greater near the edges and decreases near the center of the wall. A flat roof normally experiences an outward pressure called uplift, and some drag force, as the moving wind hits the static structure. Side walls that are parallel to the wind direction experience drag as well. The pressure on a pitched roof depends on the roof slope and building dimensions. Edges, eaves, and overhangs generally receive higher wind pressures (figure 7.1).

Figure 7.1. Variable pressures on a pitched roof



Source: Author.

Engineering design principles and methodologies

According to U.S. building codes, buildings should be able to resist minor earthquakes without any damage, and moderate earthquakes without structural damage. In the case of a major earthquake, a building should not collapse, and any structural or nonstructural damage must be repairable. The main concern of building codes is the protection of life and the safety of building occupants.

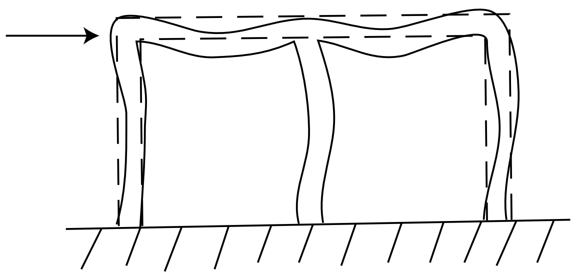
In engineering design methodologies, there are some general similarities between wind design and earthquake design. In order to simplify design calculations, both wind and seismic forces are generally treated as lateral forces applied on structures. These forces, however, are calculated differently.

The International Building Code (IBC), applied in the United States, classifies buildings into four different occupancy categories. Different values of an importance factor are assigned based on the occupancy category. This factor is used in calculating the wind or earthquake forces for which a structure must be designed. Buildings in the higher occupancy categories receive a higher importance factor and are therefore designed for larger wind and earthquake forces. Subsequently, these buildings are stronger, thus offering better resistance to shock. Buildings in Category IV include essential facilities that are expected to continue to function in the event of a wind or earthquake hazard. These include hospitals, fire fighting and rescue services, and police stations. Schools and educational facilities are generally classified in Category III, which includes elementary and secondary schools with an occupant load of more than 250, as well as colleges and adult educational facilities with an occupant load greater than 500. Compared with the value of Category II, the importance factor is 25 percent greater for Category III and 50 percent greater for Category IV.

Structural systems used to resist wind and earthquake forces are referred to as lateral load resisting systems and are classified into three major categories:

- *Moment-resisting frames.* These systems absorb energy and resist lateral forces by bending (figure 7.2). Such frames are often constructed using structural steel or reinforced concrete.
- *Braced frames.* In these frames, various types of bracing help absorb energy by developing axial tension or compression forces in the bracing system (figure 7.3).
- *Shear walls.* A shear wall resists lateral forces by developing shear stresses

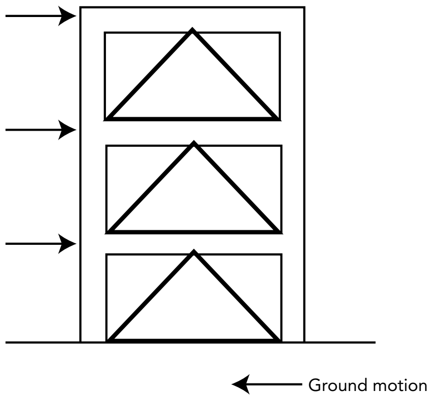
Figure 7.2. Moment-resisting frames absorb energy and resist lateral forces



Source: Author.

within the wall's plane. These may be built using reinforced concrete, reinforced masonry, steel, or wood studs with a facing of plywood or similar material. Shear walls must be properly placed in a symmetrical and balanced fashion and are often located around a building's central core or its perimeter.

Figure 7.3. Braced frame (chevron bracing)



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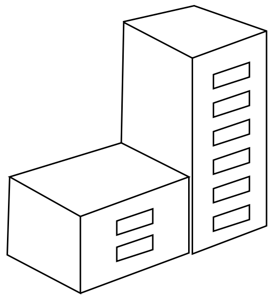
Building forms

For better stability, designers must follow these general recommendations:

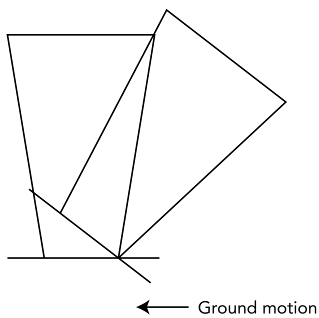
- Buildings and structures should be regular, with no important discontinuities in plan or elevation. When unavoidable, irregularities must be properly addressed in the design process.
- If a building includes masses of different sizes, then it is necessary to completely separate the masses and disconnect their structural systems. This is referred to as seismic separation (figure 7.4).
- L-, T-, U-, and cross-shaped building plans should be avoided. The corners of buildings with such plans are known as "reentrant corners" and are generally weak and in need of strengthening by the addition of horizontal structural elements that transfer loads from the corner to the other side of a building. These elements are called "collectors" or "drag struts." Building masses can also be separated at these corners.
- Building elevation forms that are thinner at the bottom and wider at the top should also be avoided. A bottom-heavy building is more stable than a top-heavy one (figure 7.5). For the same reason, heavy loads and equipment (such as water tanks and air-conditioning units) should be placed in the lower levels of a building; locating them on the roof or near the top of a building is inadvisable.

Figure 7.4. Seismic separation



Source: Author.

Figure 7.5. Top-heavy buildings are less stable



Source: Author.

Seismic base isolation

In seismic design, base isolation is another promising technology that is increasingly gaining interest in seismically active areas worldwide. Although it does not make a structure earthquake proof, base isolation is yielding some excellent improvements in the seismic resistance of both buildings and bridges. The principle of base isolation is simple: base isolators decouple the building from the ground and thus dampen the effect of an earthquake's motion. They are used in new constructions and in retrofitting existing structures.

There are generally two types of base-isolation systems. The most common is made of elastomeric bearings that include layers of rubber or neoprene and steel bearings. A steel plate normally provides the connection to the structure. A building is placed on steel and rubber isolators at the base of its columns, between the structure and its foundation. The isolators act like springs and are laterally more flexible than the building. As a result, most of the lateral movement takes place in the isolators, thus reducing motion and forces in the structure itself (figure 7.6). The isolators often have a lead core that helps dissipate energy and gives the structure some damping power.

The second type of base isolation consists of a sliding system that limits the transfer of shear forces to the structure. Many sliding systems have been developed and used; some include a special type of sand at the sliding interface, while others have a Teflon or a lead-bronze plate that slides on stainless steel. Sizes of base isolators vary. For example, Dynamic Isolation Systems (DIS 2010), one of the leading fabricators of base isolators in the United States, fabricates base isolators that vary in diameter from 12 to 60 inches (305 to 1,550 millimeters, mm), allowing for a maximum lateral displacement between 6 and 36 inches (150 to 910 mm).

Figure 7.6a. Seismically isolated structure

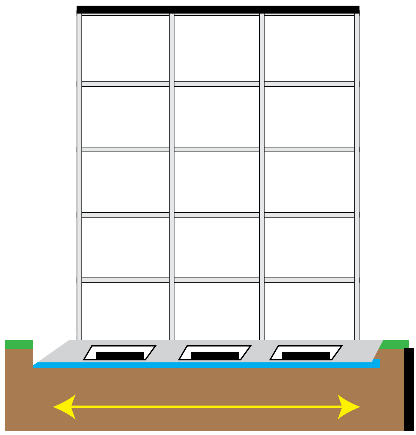
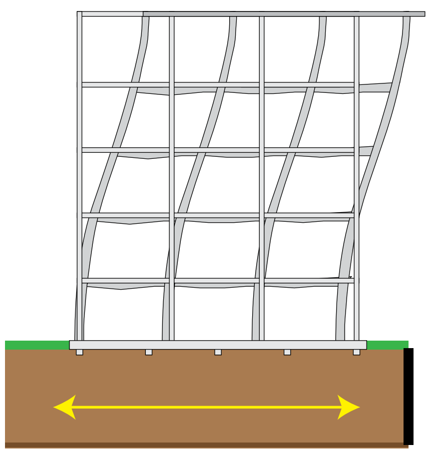


Figure 7.6b. Conventional structure



Source: Author.

Base isolation is estimated to reduce the forces and displacements in a building by up to 75 percent, most often allowing it to continue to function with practically little or no damage.

The cost of base isolators varies depending on their sizes. For small sizes, the cost per unit ranges between $2,000 and $3,000; for large isolators (60 inches or 1,550 mm), the cost per base isolator is between $30,000 and $35,000.

At the present time, base isolation is mostly used in important facilities such as hospitals, buildings with valuable contents (such as high-tech facilities), high-occupancy buildings, and historic structures. In recent years, research supported by the United Nations Industrial Development Organization (UNIDO) has led to the development of low-cost isolation systems for developing countries. Demonstration projects have taken place in Indonesia, China, and Armenia (Kelly 1998). The use of base isolation leads to cost savings by allowing a building to survive an earthquake with little or no damage, and by allowing it to continue to function, thus eliminating or reducing business interruptions that can be lengthy and expensive in the aftermath of an earthquake.

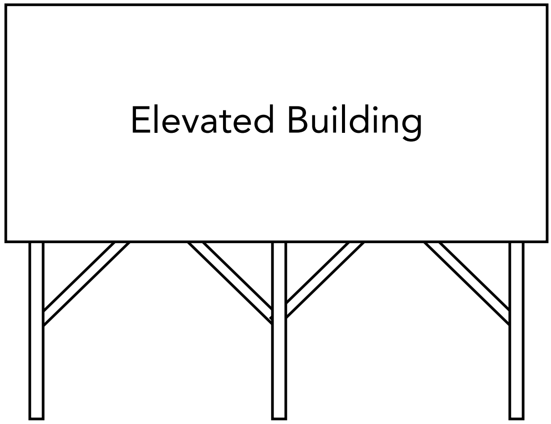
Hurricane-resistant design and construction

In the past 30 years, investigations carried out in the aftermath of hurricanes and other windstorm events have provided important lessons. The failure and loss of roofs, owing to the large uplift forces exerted by high winds, are among the most typical effects of high winds and hurricanes. Loss of roofing often results in water damage to the interior of a building from the heavy rains that generally accompany hurricanes. Other reported problems include failures of gable end walls, failures of base connections and anchor bolt pullouts, weld failures between a column and its base plate, and failures of connections between walls (FEMA 1993). Structural failure is often a progressive process in which the collapse of one element leads to the failure of another. For instance, a roof collapse may trigger a chain reaction leading to a progressive collapse of the structure.

Research and wind-tunnel tests carried out using reduced-scale models of buildings and homes show that a roof with multiple slopes, such as a hip roof (four slopes), performs better against wind forces than does a gable roof with two slopes (Gandemer and Hélary-Moreau 1999). Gable roofs are more common in construction because they are generally cheaper to build. The optimal roof slope was estimated by wind researchers to be about 30 degrees. Wind-tunnel tests also show the ridge area of a roof to be the zone of highest depression. Wind pressures tend to be larger on roof edges and eaves. To reduce wind uplift forces on a roof, an opening in an area of negative wind pressure would alleviate and balance indoor and outdoor wind pressures. Such openings, best located close to the ridge, can also be used for natural ventilation. Also, roof overhangs must be kept short—not exceeding 20 inches (50 centimeters) in length—in order to limit their vulnerability to uplift forces, since their collapse can trigger a wider roof failure.

During a hurricane, foundations are at risk from wind forces, flooding, and waterborne debris, especially in coastal areas. Wave action can also cause "scour"—when a building is poorly attached to its foundation, flood waters may cause the building to float. Elevating a structure on an open foundation, or piles, reduces the risk of flood damage. To minimize the risk of scour, it is necessary to increase the penetration depth of piles, especially in sandy soils (clay is generally less affected by scour). Piles must be braced to better resist lateral forces, as shown in figure 7.7 (Taher 2009).

Figure 7.7. Braced piles to resist scour



Source: Author.

Construction materials and methods

Good construction materials generally make a building stronger against wind loads, earthquake forces, and flooding. Reinforced concrete and masonry constructions are widely used in South America, the Caribbean, and other vulnerable places around the world. Special attention must be paid to connections in building construction, as they are generally vulnerable and must be strengthened. In cast-in-place concrete constructions, connections tend to be generally stronger because of the monolithic construction of site-cast concrete. Building codes and standards generally specify the details of reinforcement, which have more stringent requirements in high-hazard areas. In masonry construction, the quality of both mortar and masonry blocks is important. Mortar binds the blocks together and prevents them from sliding. Masonry blocks must have vertical and horizontal reinforcement, and voids must be filled with concrete. Connections between masonry walls can be strengthened using bond beams, which consist of U-shaped concrete blocks with concrete cast in them. This must be made continuous by tying the wall tops together and increasing their lateral resistance. In high-hazard areas, masonry walls often tend to separate at corners due to inadequate connections between walls, which leads to an independent movement of the walls, causing them to fail.

In hurricane-prone areas, the selection of roof coverings is especially important. It is generally recommended to use asphalt roof shingles with high bond strength. Tile roof coverings are brittle, and broken tile pieces tend to become windborne missiles. Roof coverings and sidings must, therefore, be well attached to the structure (FEMA 2000). Windows and skylights must be strong enough to resist wind pressures and breakage from windborne debris. Glazing must generally be protected with hurricane shutters that can be made from plywood panels. Shutters must be attached to the wall and not to the window frame.

Finally, it is important to keep in mind that the application and enforcement of building codes are extremely important. According to some studies, about 25 percent of insurance losses from Hurricane Andrew in the United States were attributed to construction that failed to meet codes because of substandard workmanship and poor enforcement.

Cost implications

The initial cost of additional mitigation measures to make buildings more resistant to hazards is generally minimal. Many of the recommended measures mentioned here are simple and can be implemented inexpensively, providing long-term benefits. The Federal Emergency Management Agency (FEMA 2000) has developed benefit/cost models that can be used to determine the value of mitigation measures. For example, FEMA estimates that the addition of storm shutters to a $250,000 house near the North Carolina coast can reduce potential damage to a building by more than $33,000 to $15,000 over a period of 30 years, adjusted to present value. After subtracting the cost of shutters (about $15,000), the potential present-value net benefit to the homeowner exceeds $17,000.

Conclusion

Earthquakes and hurricanes are natural hazards that will continue to cause death, injury, and destruction and unfortunately cannot be stopped. With the effects of climate change, hurricanes are expected to worsen and spread. The effects of these hazards can, however, be better mitigated, and their damages to structures reduced, through better design and construction practices.

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8

Reconstruction and Prevention in Earthquake and Hurricane Preparedness: Examples of Safe School Architecture

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The goal of architecture in educational facilities is to develop learning environments that respond to particular conditions in both curriculum and the teaching-learning process and that support the development of social, cultural, and economic principles appropriate to different demographic conditions.

Based on this objective, we propose specific architectural strategies for student development, keeping in mind the objectives of educational spaces and the context in which knowledge is generated.

What is educational architecture?

Educational architecture is suitable for educational purposes and related to the operational design of the space. It is symbolic and visually pleasing, and it provides learning opportunities. It creates a healthy and safe environment and provides green and eco-friendly spaces.

Educational architecture must incorporate the fact that education systems are developed in response to the changing demands and characteristics of a society. For this reason, school building construction faces a series of challenges, six of which are as follows:

- Designing schools for a changing world
- Increasing accessibility to education through school building design
- Involving those in charge as well as those who will use the school building
- Conceiving of the school building as a learning tool
- Designing sustainable, safe, and comfortable school buildings
- Ensuring quality designs.

Throughout the world, there are examples of how the forces of nature have had an impact on, among other things, school buildings. Earthquakes and other natural disasters cause many schools to disappear and have even made education systems collapse. Some examples may be useful as a guide to confronting the new challenges in educational architecture.

Examples from Italy

Surrounded by seas and located on geological fault lines and near volcanic activity, Italy is one of a number of countries with vulnerable buildings. The country has not forgotten the case of the San Giuliano School in Molise in 2002. This area was not classified as a seismic zone and therefore no special criteria had been incorporated into the structural design. This, along with an increase in weight on the roof supports and an amplification of seismic waves of up to magnitude 8 at the school site, led to the collapse of the school building.

Following the collapse, Italy accelerated research on earthquake risks throughout the country. As an immediate consequence of the Molise quake, the Italian Department of Civil Protection pushed for a rezoning of risk areas in Italy, a new building code, and a rehabilitation program for public buildings.

Some elements the department noted that played a key role in the lack of seismic safety up to that point included: concrete buildings erected prior to 1980 and made of low quality materials; nonexistent or unsuitable isolation joints; separation joints on site lacking proper separation; and corrosion affecting iron structures.

Building code standards were raised considerably in 2003, requiring architectural and structural designs to meet new criteria for slab-wall connections, beam-column connections; structurally compatible elements; and combinations of concrete and steel. The most substantial changes to architectural and structural designs pertain to windows, entrances and exits, teaching and learning areas, and hallways. Designs are more conservative.

Table 8.1. Italian legal and regulatory initiatives in response to the disaster of 2002

Special Plan to Increase Structural Safety in Educational Buildings (Law 289/2002, Article 80)	€460 million for seismic safety in schools; Average cost per school: €210,000.
Law 3274/2003	Seismic classification, regulations for new buildings
Law 3278/2003, Article 2	Owners of public buildings that are more than five years old must carry out a seismic assessment; Pre-1984, Zones 1-2.
Law 3362/2004	€200 million in grants for structural safety activities in public buildings.

Today, the school at San Giuliano has been protected by an "isolated footing" system. This system is being used in new schools as well as in existing ones.

This experience has given rise to a number of legal and regulatory initiatives, as detailed in table 8.1.

Practices employed in Italy include advanced foundation technologies; reliable vulnerability assessments; definition of safety levels according to a building's life span; decisions on whether to restructure or rebuild; construction according to new regulations; and updated seismic zoning.

Examples from Japan

Japan's vulnerability to seismic events was tragically apparent in the earthquake, tsunami, and ensuing nuclear crisis that struck the country on March 11, 2011. It was the worst of the six serious earthquakes that have struck Japan since 2000.

Schools are meeting places in Japan. This is one of their main roles. They also function as disaster shelters. Thus, a seismic reinforcement project following the ten-level Japanese seismic intensity scale was designed with constant assessments carried out under the program. Of more than 124,000 school buildings (40 percent of which were built before 1980), two-thirds were modified following assessment. Only 2.6 percent of the buildings were not given a seismic assessment.

In addition, the Japanese government has provided subsidies for new buildings and seismic retrofitting and for remodeling or reconstruction. (See Bill for Urgent Measures and Economic Resources Related to Resulting Measures in the Case of a Major Earthquake; planning stages: 1996–2000, 2001–2005, and 2006–2010.) Note, however, that the most recent revision was prior to the Sichuan earthquake in China and the March 2011 quake in northeast Japan.

A few of the seismic-resistance techniques in use in Japan are (a) steel casing between columns, an expensive step that nevertheless can be done quickly and without affecting school activities; (b) reinforcement of interior walls with concrete and steel, a less-expensive but more disruptive and time-consuming process that may affect subsequent use of the space; (c) carbon-fiber or copper sheathing, a high-cost option used if the first two options are not practicable; and (d) exterior frames, which essentially creates an additional structure—at a high cost.

Examples from Mexico

The main risks in Mexico are hydrological disasters, volcanoes, and earthquakes. Mexico suffered more than 30 earthquakes with a magnitude of over 7.5 between 1900 and 2010; an additional 37 such events were recorded between 1492 and 1900. Among the most severe earthquakes are those that took place in Jalisco in 1932 and Mexico City in 1985. The 1985 quake spurred the creation of civil protection policies in response to the high human and material losses, including 6,000 dead and about 411 million pesos in damage. Schools suffered more than 1,700 cases of severe damage and another 800 cases of moderate damage.

Mexico is currently fostering research and development in anti-seismic technology. It has developed a building code, norms, a national seismic hazard map, and a seismic alert system, among other strategies.

The Mexico City Design Regulations (RCDF—*Reglamento de Construcción del Distrito Federal*) govern the design of school buildings. The RCDF has been updated several times between 1942 and 2004 to incorporate the wisdom of other public works design manuals, such as that of the Federal Electricity Commission (*Comisión Federal de Electricidad*), on earthquakes, wind, etc.

The regulations of the National Institute for Educational Facilities (INIFED—*Instituto Nacional de la Infraestructura Física Educativa*) regulations also apply to school construction. INIFED's regulations cover terminology, preliminary studies (including site selection), livability and functionality (architectural and furniture designs and regulations for persons with disabilities), safety (with respect to earthquakes and other events, including potential construction materials), and issues regarding electrical installations and plumbing and sanitation.

Additional regulations consist of what are known as the "Mexican Norms," particularly those found under NMX-R-003-SCFI-2004 Schools—Building Site Selection—Requirements, which are used to identify and select sites suitable for public school construction with federal, state, municipal, or mixed participation. These apply to all levels of education nationwide.

For instance, Item 6.1 of NMX-R-003-SCFI-2004 outlines environmental conditions under which school construction would be unsuitable, specifying that sites with one or several of the following natural conditions should be avoided:

- Near rivers at risk of flooding
- Subject to hydric erosion
- Less than 500 meters from caves or unstable river bends
- On geological or active faults
- In gullies, ravines, or canyons susceptible to erosion and associated with intense rainfall
- On landfills that contain industrial or chemical waste materials.

The norms also include recommendations for building techniques. For instance, wind bracing, which is low cost and relatively quick, centers on the external reinforcement of the building. Other techniques that are more focused on risk aversion include (a) internal wall reinforcement using concrete and steel, a long-term process that is generally fairly expensive and that disrupts building activities and may create unwanted divisions in the use of the space, and (b) rigidization with steel braces, a process that involves the laying of prestressed cables and, depending on the situation, the laying of cables anchored to the foundation and roof in blocks added to the structure with mechanical connectors.

PART 5

The Impact of School Infrastructure on Learning

9

Building Achievement: Exploiting the Relationship between Architecture and Learning

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If buildings played no role in the education of future generations, then ignoring their design and deterioration could be tolerated, provided issues of structural integrity, efficiency, and safety were addressed. However, more than 60 years of research from the United States and around the world indicate a positive relationship between building quality and student achievement. For example, Cash (1993) reports that the condition of a facility can account for as many as 11 percentile points on student accountability assessments.

A 2006 publication of the American Federation of Teachers (AFT), *Building Minds, Minding Buildings: Turning Crumbling Schools into Environments for Learning*, was commissioned in response to Section 5414 of the No Child Left Behind Act, specifically the "health and learning impacts of environmentally unhealthy public school buildings on students and teachers" (p. 1). The AFT report finds that "poor environments in schools . . . adversely influence the health, performance, and attendance of students" (p. 1). Factors such as poor lighting, inadequate ventilation, crumbling walls, damaged ceiling tiles, and inoperative heating and air-conditioning systems are cited. Noise, overcrowding, and air quality are also recognized for their link to student learning (AFT 2006).

Research model

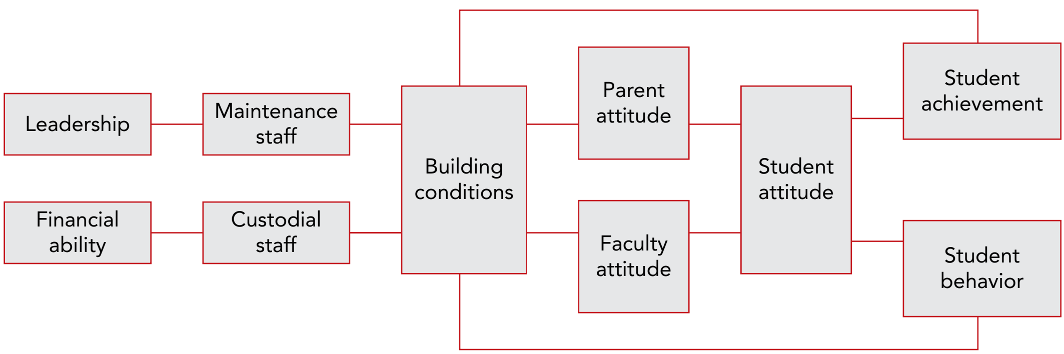
If, as research has suggested, a relationship can be found between the school's physical environment and student outcome variables, then school leadership can make informed decisions that will potentially affect student behavior and achievement. To describe the proposed interconnections among a variety of factors that relate to building conditions and student outcomes, Cash developed a theoretical research model (see figure 9.1). In it, attention is directed to student achievement and behavior as affected by the quality of school facilities.

A theoretical model that addresses the relationship between building conditions and selected student outcomes would be incomplete if it failed to address the set of circumstances that *preceded* current building conditions—and the factors that brought the building to its current condition.

The original set of circumstances may be attributable to a number of factors: the funding level for education, the value placed on education by the community, other external factors that affected the initial quality of the facility, the resources available to maintain the facility, and the selection of school personnel in leadership positions.

School leadership may include a school board, a superintendent, or perhaps an educational institution that helps school personnel develop and internalize a particular philosophy of education. Leaders determine the direction that local education will take and set the value accorded to school buildings. If the value is high, then emphasis will be placed on creating a physical environment that promotes quality education and is grounded in research. This emphasis will result in securing adequate maintenance and custodial staff and providing them the necessary training, supervision, and resources to assure their

Figure 9.1 Cash research model on school facility conditions and student outcomes



Source: Author's own compilation.

success. What the leaders communicate as important to the vision of the school, the staff will interpret as important in their performance.

The condition of a building is a product of its maintenance and custodial quality—if not initially, then certainly as it weathers time. As buildings age, maintenance deferred multiplies the need for additional maintenance; poor custodial performance only exacerbates the problem.

The research model presented in figure 9.1 contends that building conditions potentially affect student achievement and student behavior both directly and indirectly. The direct impact to student achievement and student behavior might come from factors such as climate control, illumination, density, acoustics, and color. The indirect impact might come from student attitudes that are influenced by both faculty and parental attitudes. Attitudes might be affected by how well a building appears to be maintained. The building's appearance is the physical expression of the community and an indication of the importance leaders place on education—if the appearance is good, it promotes a positive attitude among those who view it and work in it.

Building conditions and student achievement

A connection between the condition of the school facility and student performance has been supported by a number of studies in the United States and other countries.

Studies in the United States that support this conclusion have been completed in:

- Virginia (Cash 1993; Earthman, Cash, and Van Berkum 1996; Lanham 1999; Earthman 1998; Hines 1996; Crook 2006; Bullock 2007)
- Pennsylvania (O'Sullivan 2006)
- Alabama (Cervantes 1999)
- Texas (O'Neill 2000; Lair 2003)
- South Carolina (Stevenson 2001)
- Indiana (Syverson 2005).

All but three of these studies used the Commonwealth Assessment of Physical Environment (CAPE) that was developed by Cash and supported by research on various physical characteristics and factors. Connected studies have also been completed outside the United States, in:

- Kuwait (Al-Enezi 2002)
- Hong Kong (Leung and Fung 2005).

Of these, Al-Enezi used the CAPE to assess building conditions in Kuwait.

Duran-Narucki's (2008) study of school building conditions, attendance, and academic achievement in New York City finds building conditions to be a predictor of student attendance and student achievement on standardized tests. These results were reported after controlling for other possible factors, including socioeconomic status, ethnicity, and teacher quality. That poorer building conditions negatively impact student attendance and that coming to school is necessary to learn are both logical arguments that continue to be supported by research.

While the cumulative effect of a school facility's condition has been related to student outcomes, further research has served to pinpoint several factors that contribute to this overall phenomenon. Those factors include lighting, thermal conditions, acoustics, cleanliness, wall color, and density.

Lighting

Research has indicated that controlled natural light and appropriate artificial light improve both the performance and health of students and teachers (Woodside 2008). Research by Conway, Epps, and Plympton (2000) supports the relationship between lighting and student test scores and health. In addition, they report that increasing the natural lighting in construction does not necessarily increase the cost of construction or operational costs. The Heschong-Mahone Group (1999; 2003) also points to the positive effect of daylight on student performance, as does Wei (2003) in a study of schools in Hong Kong.

AFT (2006) points to key indicators that a school is committed to high standards. These include building and classroom sizes conducive to learning, adequate ventilation, heating and air-conditioning systems, extensive use of natural light, acoustic materials that reduce noise levels that interfere with learning, effective mitigation of safety and security concerns, integrated technology, infrastructure that supports special-needs students, and sufficient staff to keep schools clean and well maintained. The publication further maintains that these conditions can be incorporated in new and old buildings.

Both the presence of sunlight and specific types of classroom lighting have been linked to improved student performance (Cash 1993; Hines 1996; Earthman, Cash, and Berkum 1996; Crook 2006). In its recommendations, the 2005 National Summit on School Design (NSSD) emphasizes daylight in learning spaces and energy-efficient and aesthetically pleasing lighting within the building. Kennedy (2008) affirms that daylight is recognized as valuable for enhanced student performance and energy conservation.

Temperature

The temperature range for optimal learning is narrow. The research of Perez, Montano, and Perez (2005) investigates the impact of classroom temperature on student performance and finds that student performance is higher when the setting ranges between 70.5 and 72.5 degrees Fahrenheit than when the temperature is set at either 61 or 81 degrees. Wargocki and others (2005) also conclude that student academic performance is negatively impacted by adverse temperature and poor ventilation in the classroom. Cash (1993) also finds that students perform better in buildings that are air conditioned.

Acoustics

If students are unable to hear, their learning will be challenged. Cash (1993) finds that student performance is lower in buildings with poor acoustics or inadequate noise inhibitors. Haines and others (2001), in a study of schools near Heathrow Airport in London, England, finds that children exposed to noise are more likely to suffer from hyperactivity, become irritated more easily, and perform poorer academically. Vilatarsana (2004) supports these conclusions on the negative effect of aircraft noise on student learning.

Cleanliness

Several factors addressed in research relate to the cleanliness of the school facility. A connection has been made between lack of graffiti, clean floors and walls, and other measures of a school's cleanliness and student academic performance. Frequent painting keeps walls clean and the environment fresh. According to the Educational Longitudinal Study of 2002 conducted by the National Center for Educational Statistics (NCES), disrepair and inadequate cleanliness are major concerns among sophomores. Overall, this national survey indicates that 66 percent of 10th grade students report at least one unacceptable building condition relating to vandalism, disrepair, or cleanliness. These conditions included trash on the floors, graffiti on the building, unclean floors or walls, bathroom stalls without doors, unrepaired ceilings, and chipped paint on the walls (Planty and DeVoe 2005). Further, it is noted that students who score in the lowest quartile of their composite achievement tests are more likely to attend schools with trash on the floors and graffiti than students who place in the highest composite achievement test quartile.

If students find building conditions to be unacceptable, their attitude toward the building is impacted by these observations, and their performance could suffer. Teacher satisfaction is also impacted by the cleanliness and condition of the building (Ruszala 2008). Attitude—whether it is the teacher's or student's—is a factor that impacts student performance, teacher performance, and teacher retention.

Wall color

Not only does the cleanliness of a school's walls affect student attitude and academic performance, but also the colors of these walls. Research indicates a preference for pastel colors over dark or white walls (Cash 1993). Further research indicates that one focal tone of medium blue, brown, or green with more neutral surrounding walls is effective in enhancing the classroom environment (Engelbrecht 2003). Engelbrecht also notes that colors and end-wall treatment can relieve eyestrain and stimulate the brain to learn. As teaching and learning become more interactive, spurred by the growing availability of research on how the brain works, a focal or teaching wall is less about where the teacher stands and more about a designated purpose. All walls are teaching walls, and the colors of those walls can enhance what is being taught within the classroom. Fielding (2006) reminds us that many built environments were created for the traditional information delivery mode, which is being replaced by a vast array of instructional strategies that meet the needs of a variety of learning styles. Fielding goes on to remind us that color and light can be used to support a variety of learning environments.

Jensen (2003) indicates that for greater cognitive impact in the classroom, the best color is sky blue tinged with red. He writes that "this combination is conducive to thoughtful study, but also to alertness" (p. 17). Cafeterias and gyms, he contends, call for different colors, based on the desired student response. To support these arguments, Jensen outlines how various colors impact the viewer, physically and emotionally.

The brain responds to color innately and also through the filter of past experience and culture. For example, black is the color of mourning in the United States and can evoke a feeling of depression, while white is the color of mourning in China and perhaps evokes that same feeling in the Chinese. Research has demonstrated the ability of the color red to increase blood pressure and the color blue to reduce it. These are physical responses to colors and can be used to enhance learning in the appropriate environment. Color decisions should be made deliberately and with knowledge of their impact on learning.

In a recent study by Ruszala (2008) that considers the relationship between teacher satisfaction and building conditions, wall paint ranks among the cosmetic factors that predict teacher satisfaction.

Student population density

Studies of student performance in overcrowded buildings indicate a correlation between overcrowding, decreased achievement, and increased incidences of misbehavior. Glassman and others (1978), in a study of high- and low-density dormitories at Auburn University, find that students in high-density dormitories have lower grade point averages and lower levels of satisfaction than those in low-density dormitories. Swift (2000) notes that elementary students housed in schools built with an architectural square footage of less than 100 square feet per student perform more poorly on standardized tests than students in schools with a square footage of more than 100 square feet per student. Studies such as these have increased educators' understanding of how density impacts student outcomes.

Other factors

The NCES longitudinal study of sophomores indicates that students are more likely to feel safe in schools with either security guards or metal detectors (Planty and Devoe 2005). Air quality is also often associated with the health and attendance rates of both students and staff.

The 2005 NSSD recommendations include several references to heating, ventilation, and air-conditioning systems to counter health concerns. The quality of school environments can be improved by temperature distribution monitoring that controls and tracks the temperature in all spaces in school buildings; air filters contribute to a healthier environment; noise monitoring maximizes acoustic quality for all students.

Jensen's (2003) research on teaching and the brain confirms the value of learning by way of peripherals. Walls are more attractive when posters and student work are displayed, enhancing the learning environment. Students learn from what is intentionally displayed on the walls in the same way they learn from lists and charts that are written on whiteboards or blackboards. Additionally, the display of student-created work as part of an enriching environment is included in Lackney's design principles and emphasized in the American Architectural Foundation's school design principles for the 21st century (NSSD 2005).

Two of the least expensive adjustments that one can make to a school are to bring live plants and music into the environment. Telling faculty that they can play music or have plants gives them permission to enhance their classroom environment. The air becomes cleaner with the addition of plants, and music establishes the mood and counters acoustical distractions. Jensen (2003) cites Federal Clean Air Council studies that find plants raise indoor oxygen levels and increase productivity by 10 percent.

The incorporation of special-use rooms that can be easily altered or adapted and contain easy-to-move furniture is conducive to a learning environment that is both interdisciplinary and interactive. Such rooms can be easily changed so that different lessons and activities can be taught within the same room.

Teacher-student interaction can be enhanced when teacher productivity is enhanced. Teacher areas that are flexible, defined but not closeted, interdisciplinary, responsive to comfort, and accessible may result in the improvement of teacher quality.

When one considers how decisions are made regarding the building or purchase of a home, one finds parallels to the types of decisions that are important in designing or improving a school—a home, of sorts, for the students in one's care. Air quality, design features, size, acoustics, wall color, and natural lighting are all considerations in this vital decision-making process.

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10

School Infrastructure and Learning in Latin American Elementary Education: An Analysis Based on UNESCO's Second Regional Comparative and Explanatory Study

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School infrastructure has traditionally been analyzed as a factor related to school coverage. Recently, however, the number of studies showing positive associations between the physical conditions of schools and students' learning has increased. Berner (1993), Cash (1993), Earthman and others (1996), and Hines (1996) have estimated statistically positive effects between variables of school infrastructure and standardized tests in several cities and states of the United States (Washington, D.C., Virginia, North Dakota, and Virginia, respectively). Other similar studies in the United States have shown similar correlations (Andersen 1999; Ayres 1999; O'Neill 2000; and Earthman 1998). Rydeen (2009) offers evidence that new school buildings improved students´ grades in tests and that some specific characteristics of these buildings related to human comfort can influence students´ achievement. Others conclude that spatial setup—including noise, heat, cold, light, and air quality—is related to the performance of both students and teachers (for example, Mark Schneider 2002; AFT 2006). There is also a consensus on the positive effects of small schools; their effect seems to be stronger on students from lower socioeconomic groups (Earthman 2002). In summary, empirical evidence from the United States indicates that students who attend schools with good conditions of infrastructure exceed, by several percentage points, the performance of students in lower-quality buildings.

In Latin America and the Caribbean, the opportunities to study the relationship between infrastructure and learning in a comparative way have been very few, owing mainly to the absence of databases with a regional scope.[1] However, the Second Regional Comparative and Explanatory Study (SERCE), conducted on16 Latin American countries in 2006, has helped overcome this limitation, as it contains information on school facilities and utilities, as well as the results of standardized tests in language, mathematics, and science.[2]

A study prepared by UNESCO using the SERCE data reveals that the physical conditions of schools may have a significant effect on students´ performance and can contribute significantly to the reduction of the learning gap that is associated with social inequality.[3] Another recent study also based on the SERCE (Duarte, Bos, and Moreno 2010) sought to identify school factors that are associated with student learning in Latin America, particularly those factors related to teachers and the school context in which they teach. The study found that the physical infrastructure of schools and the presence of utilities (electricity, drinking water, sewerage, and telephone) are highly associated with learning, even after controlling for teachers' age and training, effective class time, violence and discrimination, and other socioeconomic variables of students´ families. Both studies suggest that better facilities and utilities in schools could create teaching environments that are much more conducive to learning. These results are important because they indicate that investing in school infrastructure and basic physical conditions is not a luxury but a necessity.

This chapter explores in detail the information on school infrastructure contained in the SERCE database, with the aim of: (i) assessing the state of elementary school infrastructure in the region and (ii) using the reported test results to analyze the relationship between school infrastructure and the academic results of students in the areas of mathematics and language in the Latin American elementary education. In the conclusions, guidelines are suggested for public policies in the area of school infrastructure.

1. Among the exceptions in the case of Latin America, the Paxson and Schady study (2002) revised the effect of investing in projects to build and renovate schools in poor districts of Peru and found positive results in school attendance rates.

2. Participating countries in reading, mathematics, and science are: Argentina, Uruguay, Paraguay, Peru, Colombia, Panama, Dominican Republic, Cuba, El Salvador and the State of Nueva León, Mexico. Participating countries only in languages and mathematics are: Chile, Brazil, Ecuador, Costa Rica, Nicaragua, Guatemala, and Mexico.

3. See UNESCO-LLECE (2008).

The state of elementary school infrastructure in Latin America

The SERCE assessed the performance of Latin American elementary school students (third and sixth grades) in the areas of language, mathematics, and science. The study administered examinations and collected information in 2006 to a representative sample of students in 16 Latin American countries, producing information on nearly 200,000 students and more than 2,500 third-grade and 2,300 sixth-grade schools. To evaluate the performance of students, the SERCE uses tests of common content from the official curricula of the countries in the region and the life-skills approach promoted by UNESCO. The dataset for the present study combines the database of students' test results with additional databases that include questions for students and their families about their socioeconomic characteristics and for principals and teachers about the characteristics of their schools.[4]

Managing the problem of missing data

To recover missing values for predictive variables we used the multiple imputation method, specifically the chained-equations technique. The method is based on the assumption that data omission can be predicted by using a set of variables that are observed, assuming that there is an arbitrary missing-data pattern, or *missingness at random (MAR)*. The chained-equations technique allows imputations on variables that have different measurement levels. The process consists of estimating a separate imputation model for each variable; the model uses the rest of variables included in the analysis as explanatory variables. Depending on the measurement level of variables, the imputation model estimates a linear, logistic, or multinomial logistic regression, depending on whether the variables are continuous, dichotomous, or categorical.[5]

At first, a set of plausible values for the variables with missing data was considered. Then those values were imputed in the original base by creating a new "complete" database. All models are estimated using the "complete" database. The SERCE database contains information collected at different levels (schools, students), so the imputation process was conducted at each level. The number of cases that are subject to analysis before and after the imputation process is reported in table 10.1. The initial sample indicates the number of cases available for analysis with available information in the explained variable (score observed in the test). This number includes cases with missing information in any of the explanatory variables. The final sample includes the total number of eligible cases for analysis after the imputation process, with valid information

4. For more details about the SERCE, see UNESCO-LLECE (2008).
5. In this study, data was imputed using the implementation of the method available in the ICE (*imputing based on chained equations*) routine in Stata (Royston 2004, 2009).

Table 10.1. Latin America, initial and final sample for the analysis

	Third grade		Sixth grade	
	Initial	Final	Initial	Final
Reading	2,562	2,409	2,326	2,138
Mathematics	2,562	2,427	2,326	2,129

Source: Authors.

in all important variables in this analysis. Average rates of valid cases after imputation exceed 90 percent of the entire region for both students and schools.

Main traits of elementary school infrastructure in Latin America

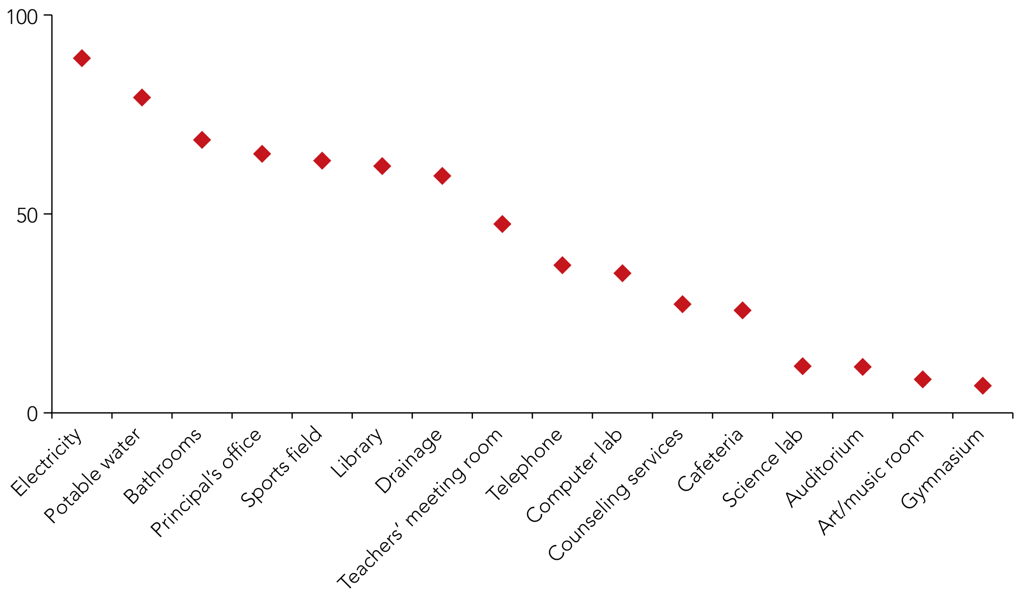
The main characteristics of the infrastructure of elementary schools in the region, as well as the chief differences by type of school (public or private), geographical location (urban or rural), and socioeconomic groups were established by using the database with the final sample. For all countries, the availability of educational spaces such as classrooms, science and computer laboratories, libraries, art and music rooms, athletic fields, and gymnasiums was analyzed. Administrative offices, teachers' lounges, and counseling services, as well as access to electricity, telephone, drinking water, toilets, and a drainage system, was also highlighted.

The analysis of data from the schools participating in the SERCE indicates that educational infrastructure and access to utilities such as electricity, water, sewerage, and telephone are deficient in the region. There is great disparity between the facilities and utilities of private urban, public urban, and rural public schools, as well as huge gaps between the infrastructure of schools that serve children from families of high and low socioeconomic incomes.

Figure 10.1 shows that, according to information from the SERCE database, infrastructural facilities and utilities in Latin American schools leave much to be desired. Among many other deficiencies, the following stand out: about 40 percent of elementary schools do not have a library; 88 percent do not have a science laboratory; 63 percent do not have spaces for meetings or offices for teachers; 73 percent do not have a cafeteria; 65 percent do not have a computer lab; and 35 percent do not have any space for athletics. Moreover, 21 percent of schools have no access to safe drinking water; 40 percent have no drainage system; 53 percent do not have telephone lines; 32 percent have too few restrooms; and 11 percent lack electricity.

Facilities and access to utilities show major differences when data is separated by urban area (private and public) and rural areas. The situation is better in urban private schools; the deficit greater in rural schools (figure 10.2). For all variables mentioned,

Figure 10.1. Infrastructure and utilities in Latin American elementary schools

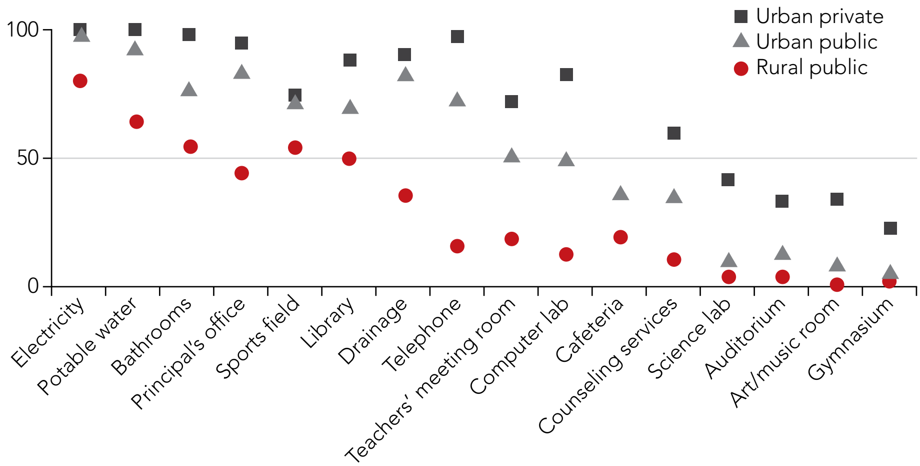


Source: Authors.

private schools have significant advantages over urban public schools and the latter, in turn, over rural schools. There are great differences in physical infrastructure and easy access to utilities between private and public schools in urban areas: the former have significant disadvantages in terms of telephone services, computer labs, restrooms, libraries, teachers' rooms, counseling services, science laboratories, auditoriums, music rooms, and gymnasiums when compared with private schools. On the other hand, the situation of rural public schools is highly precarious, as illustrated in figure 10.2. Science laboratories, computer rooms, auditoriums, gymnasiums, and space for art and music are almost nonexistent. Only a small percentage have telephone lines, drainage systems, or an office for the school principal; only half have space for a library, athletic field, or adequate restrooms. The data, broken down by country, type of school, and geographical area, appear in annex 10.1.

Similarly, according to information from the SERCE database, there are large gaps in the conditions of schools that serve the poorest children compared with schools serving children from wealthier families. The conditions of schools that serve the poorest quintile are highly deficient: only half are equipped with electricity and water, just 19 percent have drainage systems, and a mere 4 percent have access to a telephone line. Almost none have science laboratories, gymnasiums, or computer labs. Only 18 percent have a

Figure 10.2. Differences in infrastructure in urban and rural schools (public and private)



Source: Authors.

cafeteria; just 42 percent a library (figure 10.3). These deficiencies minimize the school´s potential to mitigate or offset the inequities that children bring from outside, as many of these shortcomings are replicated in students' homes.[6]

Disaggregation by country

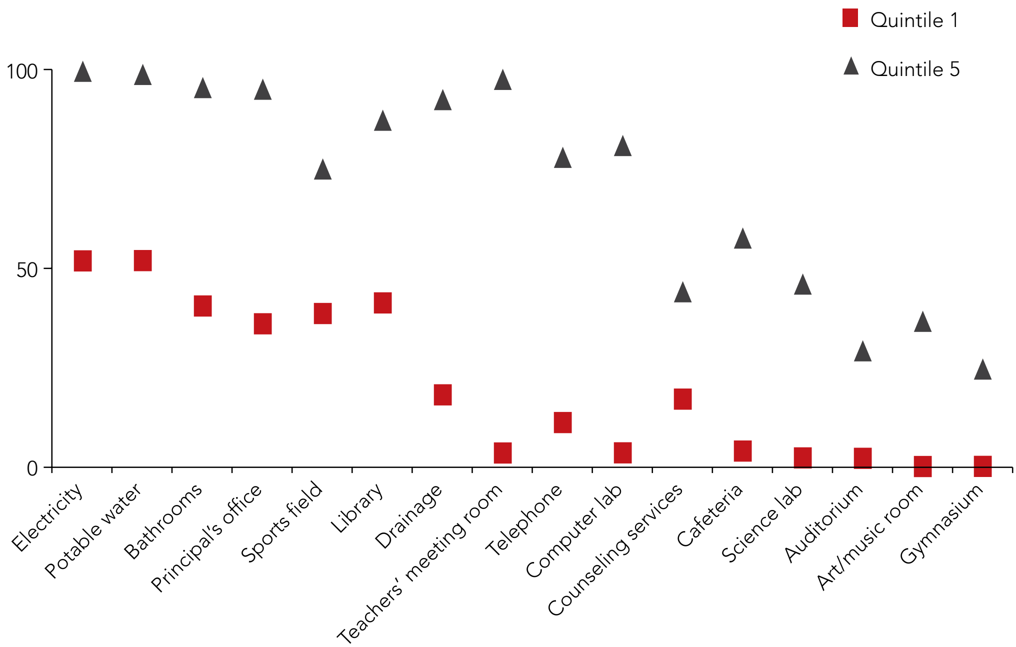
According to the information in the SERCE database study, school infrastructure in the region shows significant variations by country. Figures 10.4, 10.5, and 10.6 show average figures by country, grouped according to different aspects of school infrastructure.

Figure 10.4 shows the variables related to schools´ access to different utilities:

- Electricity is the most widely spread utility in Latin American schools. However, there are major gaps, especially in some countries of Central America and in Peru. In Nicaragua almost 60 percent of the schools lack electricity, 44 percent in Peru. In Panama and Guatemala approximately one school in three lacks electricity.

6. The socioeconomic position of the families of students who participated in the SERCE tests was calculated by using the Index of Socio-Economic and Cultural status (ISEC), created by the SERCE and based on the education variables of parents, housing characteristics, access to utilities, and family access to cultural goods (especially books at home). Using this index, the average ISEC for each school and the quintiles for the region as a whole were estimated, taking into account the importance of sample design for each country.

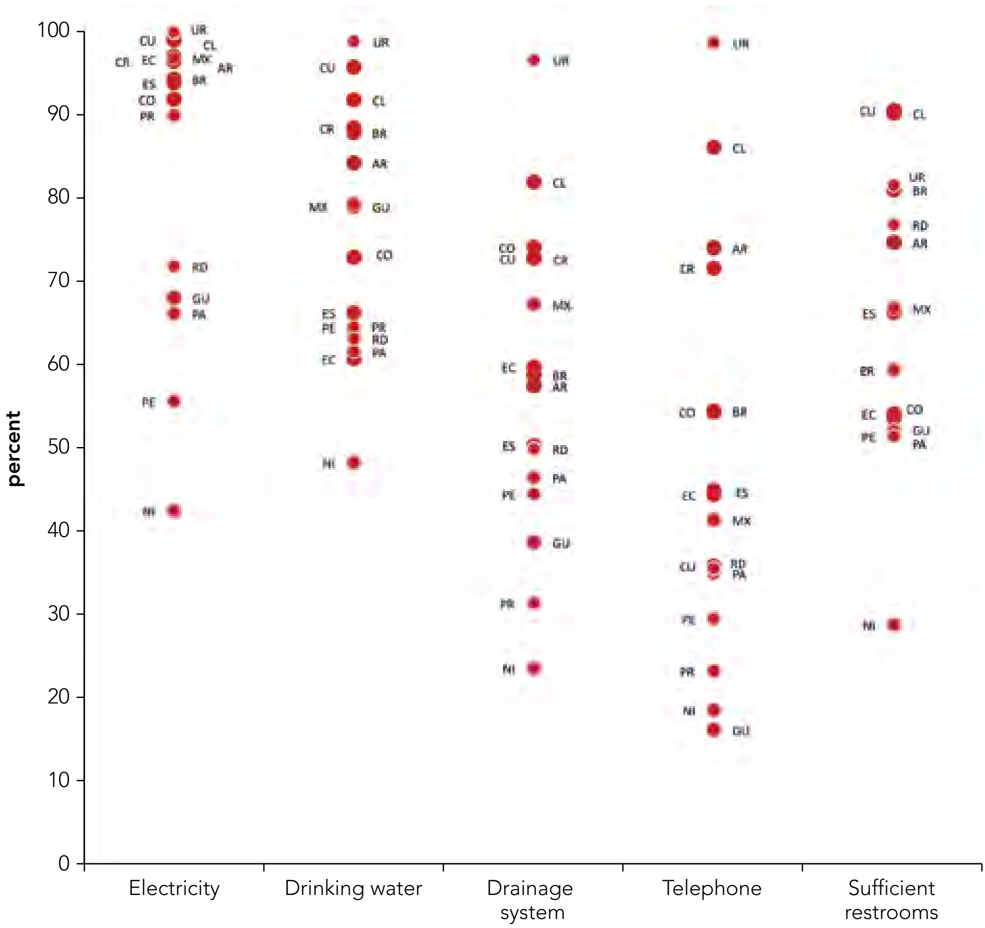
Figure 10.3. Percentage of schools with utilities according to their socioeconomic status



Source: Authors.

- While nearly 80 percent of the schools in the region have drinking water, there are significant lags in access to this service in almost all Central American countries (with the exception of Costa Rica) and in Colombia, Peru, Ecuador, and Paraguay.
- Latin American elementary schools generally have poor access to drainage systems (on average fewer than 60 percent have such access), but the situation is most critical in Nicaragua, Paraguay, Guatemala, Peru, Panama, the Dominican Republic, and El Salvador.
- The dial-up Internet connection of schools in the region is poor, with half of schools lacking access. In Nicaragua and Guatemala less than 20 percent of the schools have a telephone. Less than 30 percent in Peru and Paraguay.
- A high proportion (nearly 70 percent) of schools in the region report a deficit of restrooms for students, but the situation is worst in Central America, Mexico, Peru, Paraguay, Ecuador, and Colombia.

Figure 10.4. Access to utilities in Latin American schools

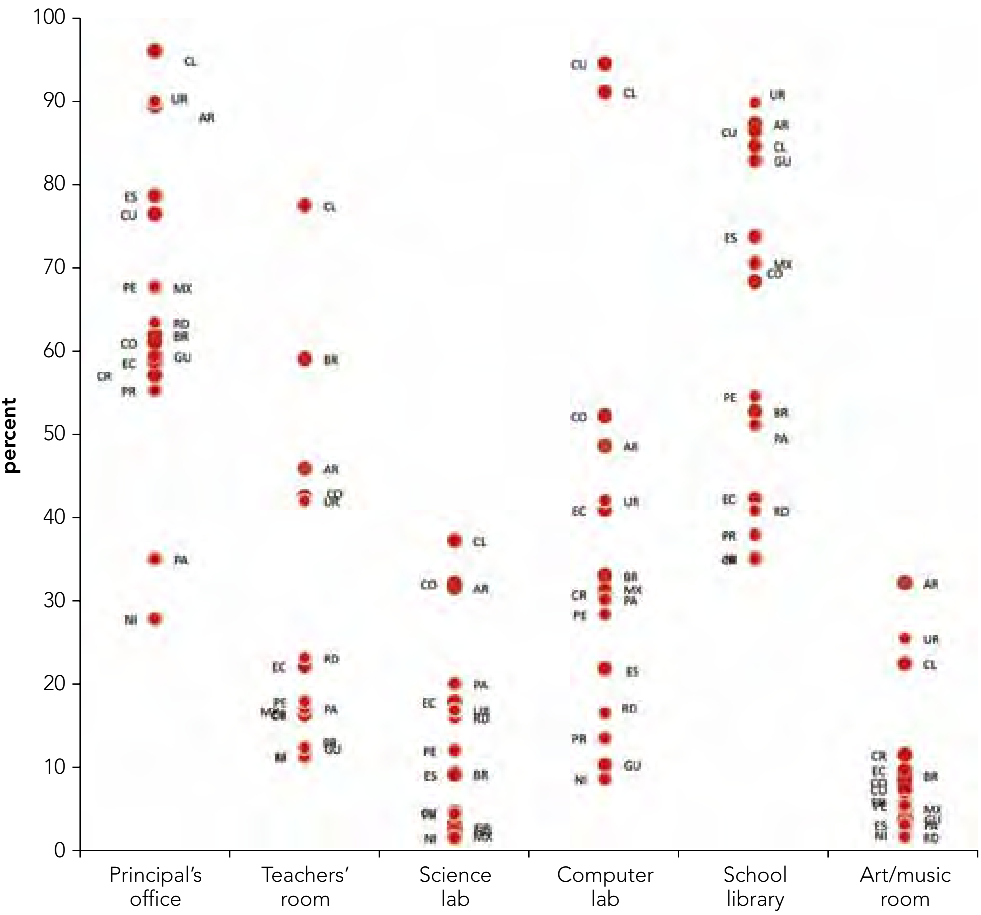


Source: Authors.

Figure 10.5 illustrates the availability of offices or other space for principals and teachers, as well as the availability of space for libraries, computer rooms, science laboratories, and art and music rooms. The variation by country is broad, and the data indicate significant deficits in all areas:

- While in Cuba and Chile the great majority of schools (more than 90 percent) have computer labs, in the rest of the countries the proportion of schools with such facilities is generally low. In Central America, the Dominican Republic, Mexico, Brazil, Peru, and Paraguay less than one-third of the schools have a computer lab.
- The deficit is even greater for science laboratories and space for the teaching of art and music. In Brazil, El Salvador, Paraguay, Cuba, Costa Rica, Guatemala, Mexico and Nicaragua, fewer than 10 percent of schools have a science laboratory. Only in

Figure 10.5. Offices for principals and teachers, and teaching support spaces



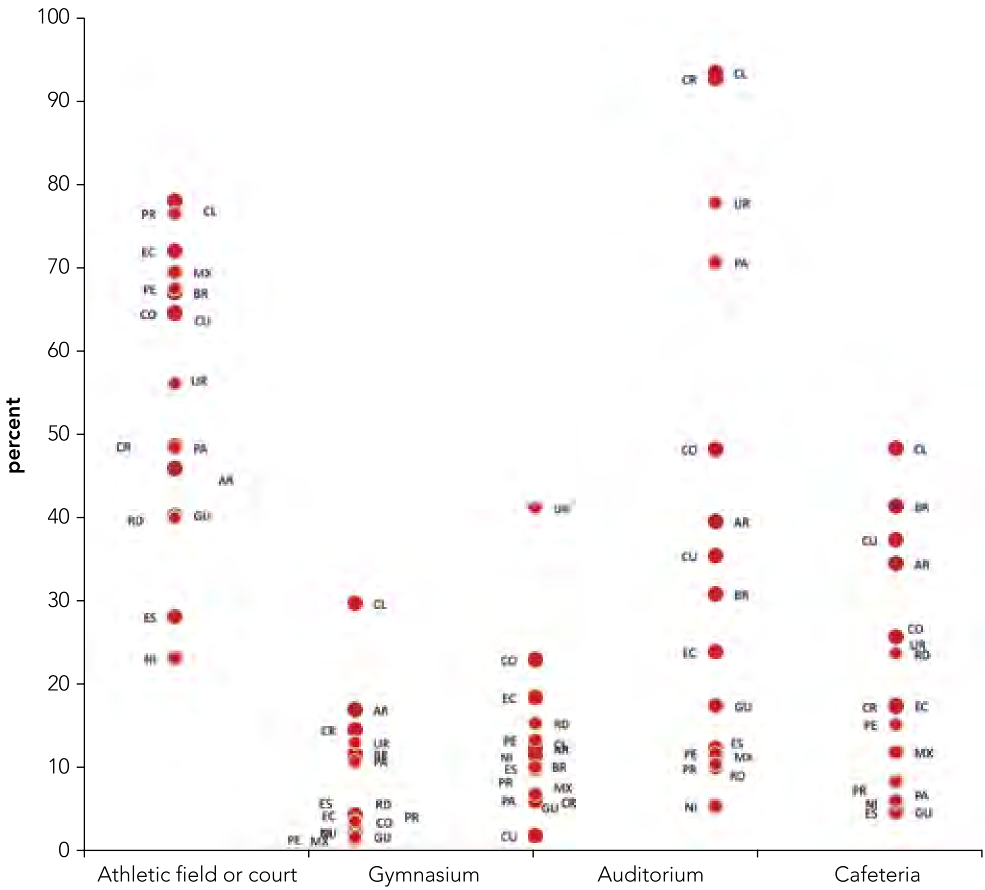
Source: Authors.

Argentina (one of every three schools) and Chile (one every five) does one find many schools equipped with art and music rooms; in the rest of the countries of the region this type of facility is almost nonexistent.

- Despite their obvious importance for the quality of education, fewer than half of schools in some the countries in the region (Nicaragua, Costa Rica, Paraguay, the Dominican Republic, and Ecuador) have a library.

Figure 10.6 provides information on the availability of space for sports, physical education, auditoriums, and cafeterias in elementary schools in Latin America. While there are large differences between countries, some kind of infrastructure for sports and, to a lesser extent, cafeterias is common. On the other hand, a general shortage of gyms and

Figure 10.6. Areas for sports, auditoriums, and cafeterias in Latin American schools



Source: Authors.

auditoriums is evident in almost all countries in the region. These facilities are most commonly found in private schools.

Figures 10.4, 10.5, and 10.6 reveal little homogeneity in the educational infrastructure of the region. Readily apparent, however, is that the schools of a group of countries show large gaps in infrastructure resources. In particular, Central American countries (except Costa Rica) and the Dominican Republic show the highest deficits, followed by Paraguay and Ecuador in South America. The physical infrastructure of schools in the countries of the Southern Cone (Chile, Argentina, and Uruguay), by contrast, have better conditions. Mexico, Brazil, and Colombia are located close to the average for the region in most of the analyzed variables. Similarly, data by country also show wide differences by geographical area (urban and rural) or by type of school (public vs. private). Disaggregated data for each of the countries are found in annex 10.1.

Relationship between infrastructure and student learning in Latin America

The results shown in the previous section reveal the main characteristics of the infrastructure of elementary schools at a regional level and disaggregated by country. This section analyzes the correlations between the main factors of school infrastructure and test results of students in the SERCE.

School infrastructure indicators

To study the correlation between school infrastructure and learning, the different facilities and utilities were grouped in thematic indexes (table 10.2).

Indexes were built using principal component analysis (PCA). This method allows the extraction of information that is common to all variables and the identification of the best linear combination of them. The result is a set of indexes that contains the weighted sum of the standardized indicators in each group. Due to the discrete nature of indicators (dichotomous variables that indicate the presence or absence of a given item), we used a variant of the PCA approach based on the analysis of a matrix of polychoric correlations was used.[7] PCA confirms the presence of multiple dimensions in the groups

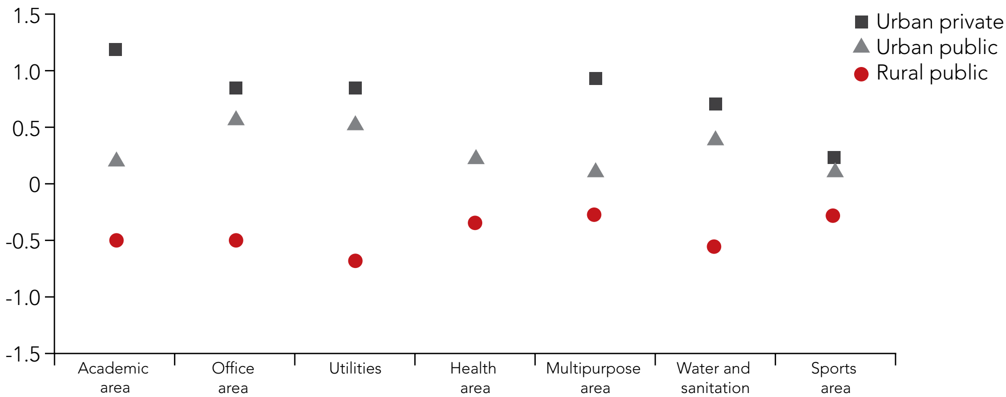
Table 10.2. Indicators of school infrastructure and components

Index	Indicators included
Sports area	Athletic field or court
Multipurpose area	Gymnasium Auditorium
Office area	Principal´s office Additional offices Teachers' conference room
Academic area	Science laboratory Computer lab Library Art/music hall
Health area	Nurse's office Counseling services
Utilities	Electricity Telephone
Water and sanitation	Drinking water Drainage system Sufficient restrooms

Source: Authors.

7. The matrix of polychoric correlations and the use of factor analysis were estimated using the *polychoric PCA* routine implemented in Stata.

Figure 10.7. Gaps in indexes by school type and geographical area (third grade)



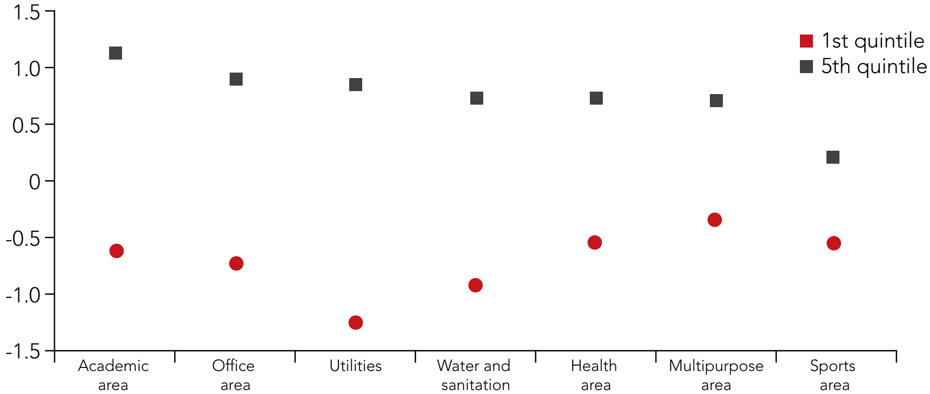
Source: Authors.

of indicators, making it possible to identify seven components or indexes (five related to facilities and two to utilities). Each index summarizes two to four indicators, except for the athletic area index that appears with a single indicator. The indexes thus created allow us to identify the first principal component, which captures between 50 and 60 percent of the common variance.

Once indexes were estimated, they were standardized so that they would have a mean value of zero and a standard deviation value of one. These indexes make it possible to summarize data and perform estimations to establish the correlation of school infrastructure with student learning.

When exploring the indexes estimates in detail, major differences (and shortcomings) in school infrastructure by geographical area, type of school, and socioeconomic groups, mentioned in the previous section, are confirmed. Figure 10.7 shows the differences between public and private schools, and between urban and rural schools. Rural schools show disadvantages in all indexes when compared to schools in urban areas. This suggests the need for targeted interventions to improve the conditions of infrastructure in rural areas of the region. But, likewise, figure 10.7 reveals large gaps in specific areas of infrastructure between urban public and private schools. In particular, deficits in urban public schools are evident in key areas related to teaching (index of academic and educational area) such as libraries, science laboratories, and computer labs; interior multipurpose area (auditoriums and gyms); and space for a nurse or counselor.

Figure 10.8. Gaps in school infrastructure indexes by students, socioeconomic status (third grade)

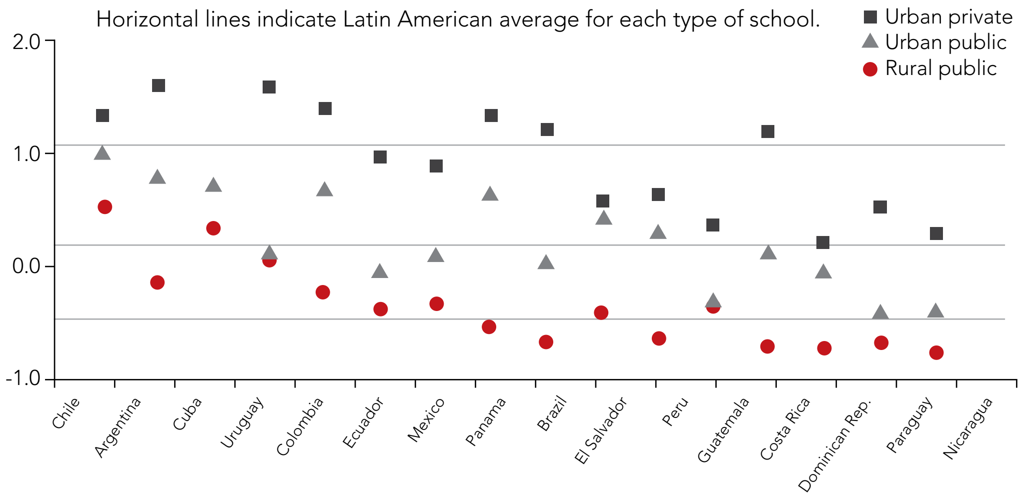


Source: Authors.

Figure 10.8 shows the gaps in infrastructure according to the socioeconomic status of schools. As noted in the second section of this chapter, the differences in the value of the indexes for the conditions of infrastructure in schools that serve the richest and the poorest quintiles are extremely marked. This indicates inequality in the education offered to different socioeconomic groups. The biggest gaps are found in access to utilities; availability of space for teaching support (library, science, and computer labs); access to water and sanitation; offices for principals and teachers; and space for nurses and counselors. The figure shows the result for the third-grade school sample, but the results for sixth-grade schools are similar.

When we look at the estimates for each index disaggregated by country, the disparity between urban and rural schools and public and private schools is evident. Figure 10.9 presents this information for academic area. The Latin American average is shown in the horizontal lines for private urban, public urban, and rural public schools. It can be observed that in the cases of Chile, Argentina, and Cuba, the three types of schools are above average in the region. On the other hand, in countries such as Nicaragua, Paraguay, and the Dominican Republic, the three types of schools are below the regional average. Likewise, the gap between private and public schools is remarkable, even those located in urban areas, in almost all countries except Chile and Brazil.

Figure 10.9. Academic space in Latin American schools by country (third grade)



Source: Authors.

Multilevel model to estimate the correlation between infrastructure and average school performance

This study estimates the correlation between learning and infrastructure at the school level using a multilevel model. Because of the nature of the dependent variable, the average score obtained by the school in each test, a linear model might have been adequate. However, because the collected information corresponds to a hierarchical data structure with schools clustered by country, it was considered appropriate to use multilevel linear regression models at two levels (schools and countries).[8] Multilevel regression models help model the variance of academic performance in schools that belong to the same educational system. It is assumed that schools in the same country tend to be more similar to each other than they are to schools in another country. Multilevel models make it possible to obtain estimations with standard adjusted errors that reflect the impact of clustering and calculate more precise significance levels, thereby avoiding a false confirmation or rejection of the null hypothesis (Type I or II errors).[9]

8. These models are also known as hierarchical linear models (HLM) or mixed models.
9. The relationship between infrastructure and test results was also estimated by using an OLS model with fixed effects. The results are similar and consistent with those of the multilevel model. The OLS model with fixed effects estimates is available to interested readers.

The relationship between school performances is represented schematically by equations (1) and (2):

At the school level (level 1).

$$Y_{ij} = \beta_{0j} + r_{ij} \tag{1}$$

At a country level (level 2).

$$\beta_{0j} = \gamma_{00} + U_{0j} \tag{2}$$

By replacing (2) for (1) we obtain an expanded model

$$Y_{ij} = \gamma_{00} + U_{0j} + r_{ij} \tag{3}$$

Assumptions:

$r_{ij} \sim \text{NID}\ (0, \sigma^2)$

$U_{0j} \sim \text{NID}\ (0, \tau_{00})$

$\text{Cov}\ (\varepsilon_{ij}, U_{0j}) = 0$

Where:

Y_{ij} : the performance of school i in country j

γ_{00} : the global intercept (overall average or performance for all schools in all countries)

β_{0j} : the intercept of country j, average performance of all schools in country j

r_{ij} : the residue of school i in country j

U_{0j} : distance (residue) to the average performance of country j with respect to the overall or regional intercept

Equation (3) shows the score in any of the tests without a control variable. This first model, known in multilevel literature as the null or empty model, is the starting point for the analytical sequence carried out (results not reported, but available upon request). Estimates obtained from the model make it possible for us (i) to get an idea of the average value of the score (intercept); (ii) establish a baseline on which to perform comparisons with more complex models; and (iii) break down the variance of the score and determine how much of that variance is associated with the school and how much with the country.

We then estimate a model that includes the school infrastructure indexes as explanatory variables. Coefficients for these estimates approximate the correlation that each index has with performance, controlling for the effect of the other indexes evaluated at their mean values (assuming that all indexes are centered). It is important to note that the econometric estimation we performed may be subject to endogeneity problems (wealthier schools with the best academic results could tend to have access to better resources, which in turn ensure they have access to better infrastructure); or may be subject to self-selection problems (students with better learning styles are "selected" or seek to register in schools with better infrastructure, thus complicating the separation of the impact of infrastructure on learning and of learning on school choice). Despite the fact that we estimated a model that included socioeconomic controls (the Index of Socio-Economic and Cultural status [ISEC] calculated by the SERCE, was part of the school level model), this does not solve all the statistical problems mentioned, so the results must be interpreted only as correlations that are subject to verification with more robust data or through impact evaluations expressly designed for the purpose of measuring the effect of infrastructure on learning. Our analysis of the correlations is therefore descriptive, but it constitutes a first attempt to explore the correlation between infrastructure and academic performance, a little-studied subject in Latin America.

Formally, the model is expressed as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}\,(INDEXES_{ij}) + r_{ij} \tag{4}$$

Where:

$$\beta_{1j} = \gamma_{10} \tag{5}$$

and $INDEXES_{ij}$ represents a vector of indexes of school infrastructure

Reordering (2) and (5), equation (4) can be rephrased as:

$$Y_{ij} = \gamma_{00} + \gamma_{10}\,(INDEXES_{ij}) + r_{ij} + U_{0j} \tag{6}$$

Controlling for socioeconomic background, the model can be expressed as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}\,(INDEXES_{ij}) + \beta_{2j}\,(ISEC_{ij}) + r_{ij} \tag{7}$$

Where:

$$\beta_{2j} = \gamma_{20} \tag{8}$$

and:

$(ISEC_{ij})$: represents a vector of socioeconomic background of the schools

Rephrasing (2), (5) and (8) in a single equation, we obtain:

$$Y_{ij} = \gamma_{00} + \gamma_{10}\,(INDEXES_{ij}) + \gamma_{20}\,(ISEC_{ij}) + r_{ij} + U_{0j} \tag{9}$$

Results of the analysis

Table 10.3 reports the results of the estimates of the multilevel models for third- and sixth-grade performance on the reading test, taking the set of data from the region, controlled for the effects of the participating countries.[10]

Separate models were calculated for schools according to their geographic location (rural and urban). Likewise, estimates were made without controls (column labeled "Without ISEC"),[11] but because school infrastructure varies with the socioeconomic background of students, estimates were also made controlling for the average ISEC of students by school and by type of school, public or private (column labeled "With ISEC"). In the SERCE, test scores are centered on a median regional score of 500 points, with each standard deviation equal to 100 points.

The most salient results of the estimates presented in table 10.3 are as follows:

- The index of academic and educational area (which includes space for libraries, science laboratories, computer labs, and art/music rooms) is the factor that is most consistently and positively correlated with the scores of students in both in third and sixth grade, as well as in rural and urban schools. The coefficients of this factor are higher in the models without socioeconomic or school-type controls, but they continue to be positive with an equal degree of significance even after introducing the controls.
- The existence of drinking water, drainage systems, and an adequate number of restrooms (water and sanitation index) and the availability of electric power and telephone service (utilities index) is positively and significantly associated with higher test scores in rural and urban schools, but only in models without socioeconomic controls. In models with ISEC, this relation ceases to be significant. Given the high relation between ISEC and learning, the change of significance between the two types of models would reflect the high correlation between the schools' ISEC and the indexes of water and sanitation and utility service.

10. The results of the analysis correspond to the correlation between factors of school infrastructure and student performance for all countries in the region. As mentioned above, the impact each national education system can have on regional data is captured when estimating the models; incorporating a country as an additional level of analysis. One advantage of this approach is that the estimated results are net representations of the differences between schools and between educational systems in each country.

11. The SERCE sample design does not consider rural private schools, so the analysis of rural schools does not control for school type.

Table 10.3. Correlation between school infrastructure and learning in reading in Latin America according to the SERCE

Index or indicator	Third grade				Sixth grade			
	Rural schools		Urban schools		Rural schools		Urban schools	
	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC
	b/p	b/p	b/p	b/p	b/p	b/p	b/p	b/p
Sports index	1.56	1.14	-1.96	1.19	3.47*	3.00*	-4.04***	-0.91
	.39	.52	.15	.30	.07	.10	.00	.44
Multipurpose area	2.71	2.74	3.56***	2.28**	-3.02	-2.89	3.33***	1.86*
	.35	.33	.01	.03	.28	.28	.01	.08
Office area	-4	-4.32	5.41**	0.19	-4.67	-4.55	6.49***	0.64
	.17	.13	.01	.92	.13	.13	.00	.73
Academic area	7.56**	6.38**	12.61***	5.57***	8.08***	6.66**	13.38***	6.01***
	.01	.03	.00	.00	.01	.02	.00	.00
Health areas	-0.6	-0.26	5.59***	1.65	3.64	4.04	4.91***	0.51
	.85	.94	.00	.16	.24	.18	.00	.66
Water and sanitation	2.45	0.1	7.95***	-0.74	5.51***	2.18	8.42***	-1.38
	.22	.96	.00	.71	.01	.30	.00	.50
Utilities	5.60**	-0.37	8.00***	-3.47*	9.90***	1.86	6.41**	-4.88**
	.01	.88	.00	.09	.00	.45	.01	.03
Socioeconomic and cultural status (ISEC)		17.47***		45.16***		22.70***		48.45***
		.00		.00		.00		.00
Public school				-20.07***				-19.02***
				.00				.00
Constant	476.49***	479.73***	495.22***	495.84***	472.14***	479.75***	489.57***	497.97***
	.00	.00	.00	.00	.00	.00	.00	.00
Distribution of variance								
Country (percentage)	50	49	49	62	44	44	41	54
School (percentage)	50	51	51	38	56	56	59	46
N	1084		1325		888		1250	

Note: Differences statistically significant at *10%, ** 5%, and *** 1%. b/p = Beta / p-value.
Source: Authors.

- In urban schools, the presence of multipurpose areas (gym and/or auditorium) has a positive effect on test results both without controls and after controlling for the socioeconomic conditions of students or for the type of school.
- In urban schools, the presence of spaces for nurse´s offices or counseling services is positively and significantly associated with learning in the model without controls, but the opposite occurs when controls are introduced, indicating a high correlation of the absence of such spaces with schools serving the most vulnerable students. The same is true of the utilities and water and sanitation indexes.

The models' estimations for mathematics scores show similar results and are reported in table 10.4.[12]

Academic area and learning

Because the index of academic and educational area shows the highest and most consistent correlations with learning, we sought to establish the variance associated with each indicator (and combination of indicators) of the index. For this purpose, we compiled scenarios to predict the variance of the mean scores of the school, using as inputs variations in the combinations of indicators that make up the index. The results are shown in table 10.5.

The analysis indicates that, on average for Latin America, a school without any of the variables (indicators) that make up the index will have a value of –1,03; one that has all variables will have an index value of 2.67. Intermediate values of this index are associated with all possible combinations of the indicators (remember that the index has a mean value of zero and a standard deviation value of one). In table 10.5, values of zero correspond to the absence of an indicator and one represents its occurrence. For example, if a school had a combination of a computer lab and a library, the value of the index would be 0.67. If, in addition, that school had a science lab, the value of the index would increase to 1.68. We repeat that these results must be interpreted with caution as they are only indicative of possible associations, owing to the econometric problems inherent in the estimation.

12. To detect multicollinearity in the models, various tests were conducted estimating the following indicators: VIF (*variance inflation factor*), Tolerance (*tolerance indicator*), and *Condition number*. The results suggest no problem of multicollinearity. In all cases, the values observed in the statistical diagnostic are lower than the cutoff values often used as a reference. On the other hand, sensitivity analyses were performed for the sample, with and without imputation (see also annex 10.2 with the omission rates of the various indicators by school type, location, and ISEC quintile). Analyses were run on both samples, and the results are highly similar. In general, they are not sensitive to the use of a sample with or without imputed data (see annexes 10.3 and 10.4 for the results of the estimations without imputation).

Table 10.4. Correlation between school infrastructure and learning in mathematics in Latin America according to the SERCE

Index or indicator	Third grade				Sixth grade			
	Rural schools		Urban schools		Rural schools		Urban schools	
	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC
	b/p	b/p	b/p	b/p	b/p	b/p	b/p	b/p
Sports index	5.19***	5.05**	-2.53*	0.12	1.8	1.45	-0.8	1.93
	.01	.01	.08	.93	.41	.50	.61	.19
Multipurpose area	1.41	1.39	3.32**	2.18*	-4.76	-4.8	4.21***	3.04**
	.66	.66	.02	.08	.14	.13	.00	.02
Office area	-6.41**	-6.56**	1.17	-3.14	-6.93*	-7.09**	3.81	-1.35
	.05	.04	.60	.12	.05	.04	.13	.55
Academic area	6.02*	5.54	13.04***	7.03***	5.66	4.68	14.02***	7.54***
	.07	.10	.00	.00	.11	.18	.00	.00
Health areas	-0.99	-0.86	4.97***	1.76	8.92**	9.39***	4.46***	0.78
	.78	.81	.00	.19	.01	.01	.01	.59
Water and sanitation	-1.94	-2.87	5.19**	-1.89	1.79	-0.69	6.93**	-1.62
	.38	.20	.04	.41	.46	.78	.01	.53
Utilities	2.33	0	4.67*	-4.46*	8.29***	2.1	3.9	-5.88**
	.34	1.00	.06	.06	.00	.47	.19	.03
Socioeconomic and cultural status (ISEC)		6.78**		35.10***		17.52***		41.69***
		.02		.00		.00		.00
Public school				-20.45***				-17.39***
				.00				.00
Constant	482.28***	483.53***	494.17***	498.81***	476.33***	482.12***	486.38***	494.64***
	.00	.00	.00	.00	.00	.00	.00	.00
Distribution of variance								
Country (percentage)	46%	46%	48%	57%	46%	46%	47%	55%
School (percentage)	54%	54%	52%	43%	54%	54%	53%	45%
N	1105		1322		888		1241	

Note: Differences statistically significant at *10%, ** 5%, and *** 1%. b/p = Beta / p-value.
Source: Authors.

Table 10.5. Value of the index of academic area by possible combinations of its component indicators

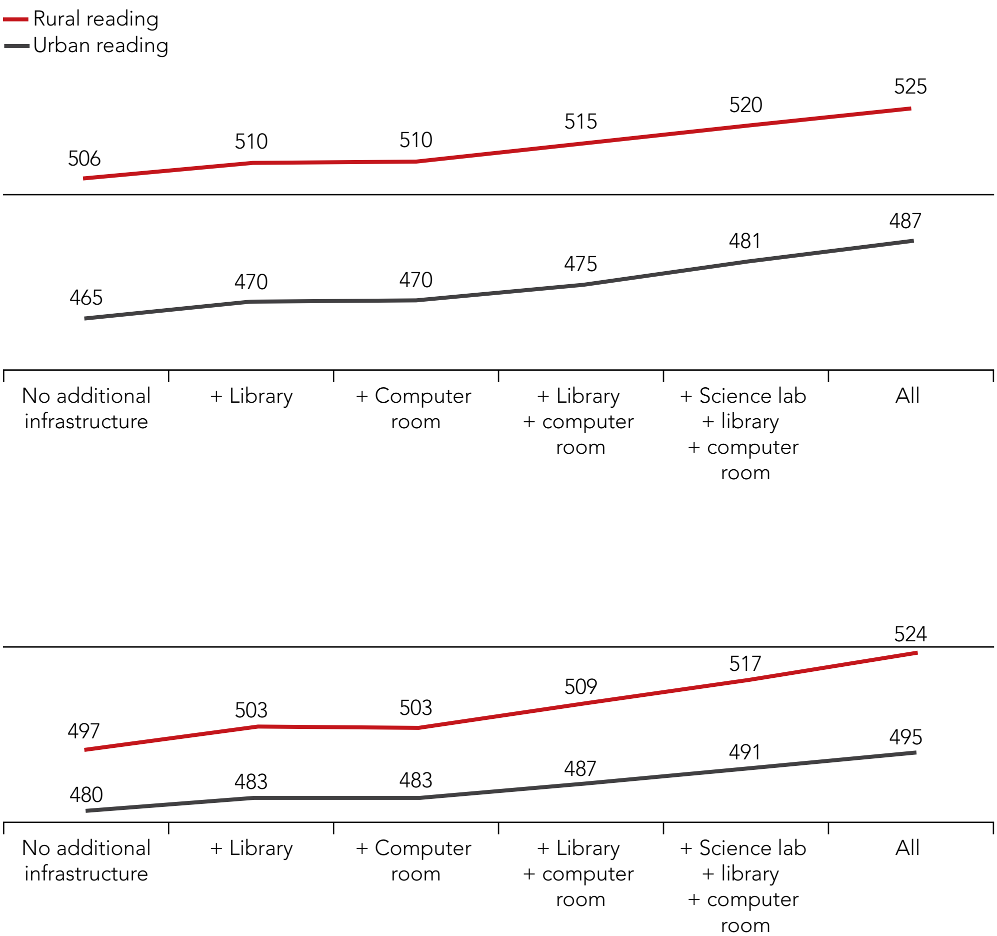
Index value	Science laboratory	Computer lab	Art/ music hall	Library	Number of schools
-1.03	0	0	0	0	645
-0.21	0	0	0	1	669
-0.15	0	1	0	0	134
-0.04	0	0	1	0	9
-0.02	1	0	0	0	5
0.67	0	1	0	1	452
0.78	0	0	1	1	22
0.80	1	0	0	1	38
0.85	0	1	1	0	7
0.86	1	1	0	0	18
1.67	0	1	1	1	61
1.68	1	1	0	1	147
1.79	1	0	1	1	11
1.85	1	1	1	0	2
2.67	1	1	1	1	123

Source: Authors.

In view of the positive and statistically significant correlation between learning and the type of school infrastructure represented by the index of academic and educational area, the difference in third-grade SERCE scores between a rural school with all the components of the index and one without any of the components suggests that their students would move from having an average reading score of 465 points to 487 points; at an urban school, the rise would be from 506 to 525 points. In mathematics at urban schools, the movement would be from 497 to 524 points, and in rural schools from 480 to 495 points. In all cases this movement represents approximately one-fifth of a standard deviation in the test scores (figure 10.10). In the SERCE tests, 20 points could be interpreted as a quarter of the gap that exists between a school achieving inadequate learning results and one achieving good results. In schools serving children with low economic resources, such a difference would help to significantly reduce the learning differences that are present in Latin American schools, not only because of the inequalities related to the socioeconomic situation of students' families, but also because of the uneven quality of the schools they attend.

Figure 10.10 presents the estimations of the effect on learning (reading and mathematics) of adding the different components of the index to an average third-grade Latin American school (according to the regression model with the previously presented controls). The figure distinguishes between urban and rural schools.

Figure 10.10. Rise in third-grade reading and math scores with additional academic and educational facilities



Source: Authors.

Conclusions

The objectives of this study were (i) to mine the SERCE database in order to present a glimpse of the state of infrastructure in elementary schools in the region and (ii) to analyze the relationships between school infrastructure and students' test results.

The results of the analysis indicate that facilities in the region's elementary schools, as well as their access to utilities such as electricity, water, a drainage system, and telephone service, are highly deficient. There is great disparity between the facilities and utilities of urban private, urban public, and rural public schools. There are great gaps between the infrastructure of schools that serve children from low-income families and those that serve wealthier families. In addition, there are large differences in the educational infrastructure when data are disaggregated by country: in particular, countries in Central America (except Costa Rica) and the Dominican Republic show the highest deficits, followed by Paraguay and Ecuador in South America, while the countries of the Southern Cone have better conditions.

From our study of the correlations between school infrastructure and results on the SERCE tests, we observe that the factors that are most highly and significantly associated with learning are the presence of space for teaching support (libraries, science laboratories, and computer labs), utilities such as electricity and telephone service, and the availability of drinking water, drainage systems, and adequate restrooms. In urban schools, in addition to the above, the presence of multipurpose areas (gyms and auditoriums) and spaces for a nurse´s office or counseling services are correlated with better student learning.

Although these results are tentative and only descriptive of the relationships that may exist between infrastructure and academic performance, they suggest that strengthening investments aimed at improving school infrastructure can help close the wide gaps that adversely affect rural areas, public schools, and schools serving students from families with lower socioeconomic resources.

According to our analysis, infrastructure investments should prioritize interventions designed to improve the infrastructure factors that are most directly associated with learning—libraries, science laboratories, computer labs, and multipurpose areas. Similarly, investments must seek to resolve the major deficits of schools in the region, especially those located in rural areas, related to the lack of drinking water, drainage systems, sufficient restrooms, electric power, and telephone service.

Finally, in order to have better tools to guide public policies in the field of school infrastructure, it is necessary to improve data on the physical characteristics of schools by country and to promote additional research at the regional level and within individual countries, to analyze the connections between school infrastructure and student learning.

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Annex 10.1 10.1. Indicators of school facilities and utilities

	Latin America	Argentina	Brazil	Colombia	Costa Rica	Cuba	Chile	Ecuador	El Salvador	Guatemala	Mexico	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Uruguay
Third-grade school facilities (percentage of schools possessing facility)																	
Athletic field or court																	
Country total	63.4	45.9	67.1	64.5	48.6	64.6	78.1	72.1	28.0	40.3	69.5	23.0	48.4	76.6	67.5	39.9	56.1
Private urban schools	73.5	58.0	94.5	62.1	84.4	100.0	82.9	83.3	36.0	72.3	57.2	56.3	72.5	74.3	45.8	54.4	59.3
Public urban schools	72.8	30.1	82.7	62.9	50.0	70.9	73.6	75.5	54.5	69.0	77.7	46.8	68.7	66.1	68.7	52.4	49.2
Public rural schools	54.4	61.9	45.6	66.3	43.8	58.2	76.1	66.3	21.7	32.8	64.6	17.0	40.0	79.1	73.6	30.4	90.7
Gymnasium																	
Country total	6.8	16.8	11.5	2.9	14.4	2.1	29.7	4.2	3.7	2.2	1.3	1.3	10.7	2.7	1.5	3.4	12.9
Private urban schools	23.1	52.7	34.3	8.8	66.7	100.0	37.6	11.0	21.0	7.6	5.1	12.5	42.3	0.0	6.3	3.6	35.0
Public rural schools	6.7	11.0	10.8	4.9	25.6	1.9	36.2	4.8	2.9	0.0	0.0	1.6	20.3	0.0	1.8	7.6	7.6
Public rural schools	2.5	2.0	4.6	0.0	4.4	2.2	14.3	1.8	1.2	1.8	1.7	0.0	3.6	3.7	0.0	1.7	3.8
Auditorium																	
Country total	11.6	12.2	11.4	22.9	6.0	1.7	12.7	18.3	9.8	6.6	5.8	9.7	6.6	10.0	13.2	15.2	41.2
Private urban schools	33.5	30.0	34.9	42.3	27.3	100.0	15.6	51.3	19.1	27.0	29.5	50.2	27.3	41.9	27.5	33.6	72.4
Public rural schools	14.4	11.3	12.3	35.0	11.7	3.3	9.0	15.3	28.9	22.0	6.1	8.5	14.7	10.5	28.9	20.6	35.6
Public rural schools	4.1	2.0	3.6	9.9	1.5	0.0	12.4	8.5	4.5	2.4	1.7	5.4	1.8	4.6	3.5	7.4	17.0
Principal's office																	
Country total	65.1	89.5	61.9	61.0	57.1	76.5	96.1	58.6	78.7	59.3	67.6	27.7	34.9	55.3	67.7	63.4	90.1
Private urban schools	93.9	100.0	89.1	95.1	100.0	100.0	100.0	92.0	95.7	95.8	100.0	82.7	95.3	89.3	93.1	100.0	100.0
Public rural schools	83.8	91.0	77.7	81.2	82.0	100.0	100.0	60.1	97.1	92.5	90.8	80.5	84.3	69.5	81.8	82.5	94.6
Public rural schools	44.6	80.0	40.1	37.6	43.4	52.0	88.2	44.5	72.5	50.8	41.9	15.5	14.5	46.7	54.7	42.8	45.3
Additional offices																	
Country total	40.4	53.9	66.5	42.6	19.7	44.4	70.3	18.9	21.3	9.0	14.3	12.2	21.7	19.7	21.8	32.3	39.1
Private urban schools	78.6	100.0	83.6	82.2	84.4	100.0	88.9	59.0	57.4	57.2	81.2	61.4	95.0	73.1	55.1	60.0	88.1
Public rural schools	57.6	64.5	90.7	59.0	44.3	67.9	86.1	8.7	40.0	15.3	12.6	31.9	56.0	28.3	36.0	55.2	30.7
Public rural schools	18.7	6.0	41.1	19.8	3.8	19.9	35.3	8.3	12.1	1.8	3.4	4.5	1.8	9.2	6.4	13.6	0.0
Teachers' conference room																	
Country total	37.1	45.9	59.0	42.5	16.3	16.2	77.5	22.0	11.1	12.2	16.8	11.1	16.9	12.2	17.8	23.0	41.9
Private urban schools	71.2	84.3	83.6	74.2	68.8	100.0	95.9	56.4	16.9	59.6	57.7	50.3	77.2	44.1	40.8	59.3	75.3
Public rural schools	51.2	48.4	76.9	56.5	27.1	24.9	85.4	16.9	34.2	25.3	21.3	14.6	25.2	14.5	33.0	25.4	36.3
Public rural schools	18.6	15.7	36.5	23.6	6.4	6.9	48.2	11.0	5.5	4.2	6.6	6.2	3.6	6.5	5.7	10.3	17.0
Science lab																	
Country total	11.7	31.5	9.0	32.0	2.9	4.4	37.2	17.7	9.0	2.3	1.6	1.3	19.9	4.2	11.9	15.8	16.7
Private urban schools	41.8	56.9	47.4	64.6	35.1	100.0	55.1	29.7	23.3	7.3	18.3	15.1	67.8	21.5	34.4	21.7	47.4
Public rural schools	11.2	34.8	2.0	43.6	0.0	4.4	34.0	15.9	22.1	0.9	0.0	0.0	54.5	2.0	23.6	28.9	8.7
Public rural schools	3.9	10.0	1.8	15.0	0.0	4.4	18.8	14.6	4.1	1.8	0.0	0.0	5.4	1.9	1.1	8.7	7.5

(continued)

	Latin America	Argentina	Brazil	Colombia	Costa Rica	Cuba	Chile	Ecuador	El Salvador	Guatemala	Mexico	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Uruguay
Computer lab																	
Country total	35.1	48.6	32.9	52.2	30.7	94.6	91.2	40.8	21.7	10.1	31.3	8.4	30.0	13.3	28.3	16.4	41.9
Private urban schools	81.7	100.0	83.6	83.3	100.0	100.0	97.5	83.3	76.8	70.5	75.4	52.8	100.0	70.0	74.1	47.0	87.9
Public rural schools	49.4	43.1	45.9	79.0	58.8	98.9	100.0	44.5	55.9	16.1	41.5	17.8	60.4	8.3	53.8	27.9	28.1
Public rural schools	12.9	21.8	6.6	26.2	12.9	90.1	76.1	23.0	6.5	1.8	14.6	2.4	11.4	5.5	6.2	1.6	40.3
Art/music room																	
Country total	8.4	32.1	8.9	8.1	11.3	7.2	22.3	9.5	2.9	3.6	4.8	1.7	2.9	5.8	5.2	1.4	25.4
Private urban schools	34.4	58.5	38.3	33.0	49.3	100.0	29.9	34.7	12.6	20.0	35.2	12.5	23.2	20.5	21.9	5.0	72.4
Public rural schools	9.2	40.3	7.9	6.5	18.9	14.2	21.9	2.3	9.9	0.0	3.8	1.6	0.0	4.2	6.7	2.3	14.3
Public rural schools	0.9	2.0	0.0	2.2	4.2	0.0	13.8	4.9	0.0	1.8	0.0	0.5	0.0	3.7	0.0	0.0	3.9
Library																	
Country total	62.0	87.4	52.7	68.4	34.9	86.4	84.7	42.2	73.8	82.9	70.5	35.0	51.1	37.9	54.5	40.8	89.9
Private urban schools	87.9	89.7	94.5	100.0	76.6	100.0	90.1	80.4	83.2	68.0	92.0	76.7	75.1	66.3	59.0	74.1	96.2
Public rural schools	70.5	92.4	66.6	69.6	60.8	96.8	83.7	32.6	90.7	77.4	70.2	57.8	73.2	47.9	75.2	48.5	89.7
Public rural schools	49.4	78.0	28.0	57.0	21.5	75.7	79.0	31.5	68.9	85.5	67.1	28.2	42.6	30.8	45.8	26.3	79.7
Nurse's office																	
Country total	5.8	5.2	2.1	15.9	6.2	13.0	38.4	10.5	2.6	2.9	3.7	0.9	5.3	3.1	6.6	5.5	4.1
Private urban schools	26.1	15.7	13.1	60.2	43.2	100.0	49.4	32.8	19.1	11.8	33.4	10.5	30.9	8.6	25.6	15.3	6.4
Public rural schools	4.2	1.6	0.0	12.4	8.1	23.7	36.8	6.9	3.1	2.6	2.0	0.0	10.5	0.0	10.1	11.8	4.0
Public rural schools	1.2	3.9	0.0	3.5	1.2	2.2	26.4	4.8	0.0	1.8	0.0	0.0	0.0	2.8	0.0	0.0	0.0
Counseling service																	
Country total	25.8	34.4	41.4	25.6	17.2	37.3	48.3	17.3	4.5	4.6	11.7	5.6	8.2	5.9	15.1	23.6	23.7
Private urban schools	59.9	58.3	69.2	64.3	88.7	100.0	54.2	49.9	25.3	26.1	41.0	31.4	59.8	30.1	71.8	67.8	73.1
Public rural schools	35.4	42.0	53.3	36.7	23.3	51.1	63.6	20.2	11.0	4.5	15.4	21.7	2.9	2.1	10.4	34.6	11.9
Public rural schools	10.5	7.9	23.9	6.4	6.6	23.3	28.5	5.2	0.0	1.8	3.5	1.1	0.0	2.8	0.0	3.9	1.9
Third-grade school utilities (percentage of schools possessing utility)																	
Drinking water																	
Country total	79.1	83.6	87.8	72.5	87.5	95.6	91.7	60.1	66.5	79.2	78.8	49.9	61.5	64.2	64.6	63.2	98.5
Private urban schools	99.0	100.0	100.0	94.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	92.6	100.0	100.0	100.0	93.1	100.0
Public rural schools	92.9	94.0	94.0	91.7	96.1	98.9	100.0	81.2	98.7	92.6	92.9	92.6	100.0	86.2	89.5	76.1	100.0
Public rural schools	64.6	56.0	79.1	53.6	83.2	92.3	74.6	34.2	55.1	75.0	63.4	40.5	46.9	53.3	44.8	47.9	87.0
Drainage system																	
Country total	59.9	56.6	59.0	74.1	72.5	72.8	81.9	59.7	50.3	39.9	67.5	25.2	47.2	32.2	44.3	50.4	96.5
Private urban schools	90.3	77.7	83.6	97.2	92.2	100.0	97.8	88.6	91.4	100.0	100.0	88.6	100.0	79.6	93.6	97.9	96.2
Public rural schools	83.4	77.1	82.0	90.2	83.1	95.8	93.4	81.0	87.8	92.6	84.5	62.2	89.7	34.9	85.9	64.5	97.3
Public rural schools	36.2	10.0	33.3	56.7	66.7	49.2	52.8	38.2	36.7	26.4	47.7	14.2	29.2	23.6	14.2	28.5	92.6
Adequate restrooms																	
Country total	68.6	75.2	80.9	54.1	58.1	90.5	90.3	53.7	66.2	52.1	66.9	30.2	51.4	59.9	51.3	76.7	81.3
Private urban schools	97.9	99.2	100.0	94.3	100.0	100.0	100.0	88.5	95.7	98.2	100.0	70.4	90.1	100.0	96.5	100.0	96.2
Public rural schools	76.4	75.8	86.9	55.6	70.6	89.6	89.7	55.6	74.7	58.0	72.5	54.7	84.6	62.7	69.3	68.3	76.1
Public rural schools	55.4	57.7	70.2	39.9	49.1	91.4	78.8	38.3	60.1	45.4	56.5	23.1	37.7	52.6	31.1	72.0	85.2

(continued)

	Latin America	Argentina	Brazil	Colombia	Costa Rica	Cuba	Chile	Ecuador	El Salvador	Guatemala	Mexico	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Uruguay
Electricity																	
Country total	89.0	96.3	94.2	91.9	95.4	98.9	99.4	96.6	93.9	68.2	96.7	42.6	66.5	89.5	54.4	72.7	99.8
Private urban schools	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.0	100.0	100.0	100.0	100.0	100.0
Public rural schools	98.7	100.0	100.0	97.4	98.2	100.0	100.0	100.0	100.0	94.5	98.1	89.3	100.0	96.1	96.5	86.1	100.0
Public rural schools	79.6	88.0	87.8	85.9	94.0	97.8	98.2	93.7	91.7	61.2	95.0	31.6	53.8	86.2	25.3	57.9	98.1
Telephone																	
Country total	47.5	74.3	54.8	54.5	70.5	36.1	86.1	44.2	45.4	17.2	41.5	20.8	36.2	24.8	28.5	36.4	98.3
Private urban schools	97.3	100.0	100.0	97.2	100.0	100.0	100.0	92.3	100.0	89.4	100.0	88.6	95.3	86.7	89.9	90.4	100.0
Public rural schools	73.2	93.8	79.5	80.7	88.8	65.0	100.0	50.3	97.2	47.8	64.4	55.9	88.6	49.1	43.3	51.9	99.5
Public rural schools	17.0	26.0	21.1	24.6	60.9	6.3	57.5	21.3	26.9	4.4	12.3	9.5	15.1	9.0	4.6	11.6	88.9
Sixth-grade school facilities (percentage of schools possessing facility)																	
Athletic field or court																	
Country total	70.1	47.5	85.7	71.8	50.0	62.9	78.8	75.5	29.6	43.1	71.1	34.7	47.8	75.3	75.3	56.0	56.4
Private urban schools	75.7	54.8	100.0	72.7	91.5	100.0	84.8	79.2	38.7	70.0	52.0	63.3	72.1	70.5	56.9	53.0	59.3
Public rural schools	73.7	31.6	82.8	75.3	47.5	70.0	74.7	77.6	56.9	70.8	77.0	50.7	68.7	66.9	71.4	70.7	49.2
Public rural schools	64.9	64.8	77.3	68.0	46.3	55.7	75.3	73.0	22.1	35.6	69.2	26.9	40.0	78.0	82.4	49.4	92.7
Gymnasium																	
Country total	10.8	18.4	24.4	3.7	14.6	2.5	30.5	7.9	5.2	3.4	4.3	2.4	9.6	3.6	1.7	10.6	12.8
Private urban schools	26.9	55.7	42.4	6.0	80.8	100.0	40.7	14.7	24.3	14.7	5.1	10.5	33.4	5.1	7.3	17.5	35.0
Public rural schools	10.6	12.6	18.6	6.3	25.9	2.8	37.6	11.5	2.7	0.9	3.8	1.6	22.5	2.0	1.8	11.9	7.6
Public rural schools	5.0	1.8	19.3	0.0	3.3	2.1	13.1	3.5	2.6	2.1	4.6	1.0	3.3	3.7	0.0	6.1	3.6
Auditorium																	
Country total	16.6	12.8	26.2	35.3	8.0	2.7	12.5	22.6	12.0	7.8	9.6	13.8	7.8	11.1	13.5	21.0	42.4
Private urban schools	37.7	30.4	42.5	60.9	38.0	100.0	16.1	55.1	22.5	30.1	29.5	52.9	34.2	44.9	23.2	28.1	72.4
Public rural schools	20.8	10.9	26.5	37.6	12.7	4.2	8.6	20.9	31.6	21.7	13.7	11.8	17.4	13.9	29.6	28.6	36.8
Public rural schools	5.4	3.6	7.6	17.0	2.9	1.1	11.6	10.3	6.0	2.8	3.1	6.9	1.6	4.6	4.1	13.1	21.8
Principal's office																	
Country total	74.1	90.3	85.0	80.5	60.1	76.3	95.7	58.3	80.2	61.1	67.4	38.8	34.4	54.2	70.3	86.3	90.1
Private urban schools	96.0	100.0	93.3	96.9	100.0	100.0	100.0	91.7	95.9	95.4	100.0	88.2	95.0	89.8	95.9	100.0	100.0
Public rural schools	88.2	90.7	86.1	81.0	81.0	100.0	100.0	57.9	97.2	93.5	92.3	84.5	84.9	70.7	85.1	93.0	94.6
Public rural schools	54.0	83.3	73.1	69.6	48.3	52.4	87.3	45.0	73.9	52.0	42.2	22.5	15.2	44.4	56.6	75.4	47.3
Additional offices																	
Country total	43.1	53.5	84.4	69.8	20.8	44.2	70.7	25.1	23.2	10.2	19.7	20.0	22.3	20.4	23.4	45.1	39.4
Private urban schools	83.8	100.0	93.3	90.9	100.0	100.0	90.7	66.7	63.2	53.1	78.9	69.1	95.0	74.5	60.1	75.9	88.1
Public rural schools	57.7	65.5	92.3	75.9	43.7	67.4	86.9	15.0	41.0	16.2	25.1	36.4	57.9	28.6	36.2	59.5	30.8
Public rural schools	15.8	5.5	54.5	50.9	3.8	20.7	34.7	13.0	12.7	3.2	6.2	8.4	3.7	9.2	7.2	20.8	3.7
Teachers' conference room																	
Country total	42.6	45.3	86.7	66.3	17.9	16.1	78.1	26.5	13.3	14.4	23.4	13.5	17.7	14.2	15.9	34.8	41.9
Private urban schools	75.9	85.0	93.3	87.8	83.1	100.0	97.5	62.5	20.3	60.6	57.7	48.5	76.1	47.0	43.2	59.7	72.4
Public rural schools	54.4	48.4	87.5	65.2	25.7	24.8	86.1	20.9	36.7	25.3	30.9	19.5	31.3	19.5	35.0	35.4	36.4
Public rural schools	20.2	14.6	77.3	53.8	7.9	7.4	49.8	14.6	7.0	6.2	12.1	6.1	5.3	7.3	0.1	21.3	20.0

(continued)

	Latin America	Argentina	Brazil	Colombia	Costa Rica	Cuba	Chile	Ecuador	El Salvador	Guatemala	Mexico	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Uruguay
Science lab																	
Country total	18.4	32.2	28.5	51.4	3.4	5.2	38.9	22.6	10.7	2.9	5.7	2.9	21.4	5.4	12.8	24.6	17.8
Private urban schools	48.4	58.6	62.0	77.9	38.0	100.0	60.1	38.8	26.5	9.8	18.3	21.5	70.7	25.5	36.1	22.9	47.4
Public rural schools	21.0	35.9	22.3	58.2	1.9	5.2	33.5	21.2	22.5	0.9	10.5	0.0	56.4	5.8	24.1	38.7	10.2
Public rural schools	5.2	9.3	7.6	28.5	0.0	5.2	19.3	16.7	5.6	2.1	0.0	0.0	6.9	1.9	1.3	17.7	9.1
Computer lab																	
Country total	44.9	49.0	61.8	70.7	30.6	94.8	90.1	42.2	23.0	11.9	35.6	14.0	30.8	14.9	31.6	26.7	42.4
Private urban schools	83.5	100.0	86.5	85.1	100.0	100.0	97.5	87.5	77.7	74.6	72.4	56.9	100.0	69.4	79.3	50.9	87.9
Public rural schools	58.3	45.3	67.4	90.6	57.5	99.0	100.0	48.9	55.0	17.0	46.6	24.0	60.4	11.8	56.8	36.2	28.3
Public rural schools	19.4	20.3	20.1	43.3	13.3	90.5	73.6	20.8	6.9	2.1	21.1	4.5	13.9	6.3	7.2	8.5	43.6
Art/music room																	
Country total	12.4	34.4	14.8	14.9	14.0	7.9	25.4	15.7	4.1	4.3	8.5	4.6	3.2	7.9	7.2	5.3	25.7
Private urban schools	39.6	61.1	49.1	39.7	62.0	100.0	34.4	35.8	12.1	22.5	27.3	21.3	21.4	24.5	32.2	10.3	72.4
Public rural schools	12.3	43.5	5.9	6.9	18.0	13.6	25.3	11.4	10.8	0.9	13.5	3.2	3.9	9.8	6.7	9.9	14.3
Public rural schools	2.4	3.8	0.0	6.6	7.2	2.1	15.3	9.5	1.3	2.1	1.5	1.8	0.0	4.6	0.0	0.0	9.1
Library																	
Country total	71.8	87.2	81.4	78.5	35.0	87.9	85.1	39.1	73.9	83.6	70.3	39.8	51.6	39.0	56.4	58.2	90.1
Private urban schools	86.9	90.2	93.3	100.0	83.1	100.0	93.3	76.3	83.9	64.9	91.1	73.3	76.1	66.3	60.5	81.4	96.2
Public rural schools	77.9	93.7	85.5	78.6	60.9	96.9	84.5	31.4	91.1	76.5	69.2	61.1	74.2	47.9	76.6	61.0	89.7
Public rural schools	61.1	76.0	58.0	64.8	20.5	78.9	76.4	27.8	68.4	87.3	68.1	30.3	43.5	32.2	46.9	44.4	81.9
Nurse's office																	
Country total	10.5	5.5	9.1	22.1	7.6	15.0	39.3	14.7	3.8	4.0	10.5	3.1	6.4	4.2	7.4	13.3	4.6
Private urban schools	27.8	13.4	16.1	66.6	46.9	100.0	49.6	42.6	18.3	12.1	33.4	16.0	32.0	8.1	28.7	20.7	6.4
Public rural schools	11.2	3.1	9.6	8.3	9.4	25.8	38.2	11.6	4.2	2.6	13.5	1.6	17.8	4.0	10.1	19.0	4.0
Public rural schools	3.7	3.6	0.0	6.6	2.6	4.2	28.7	4.9	1.3	2.9	4.7	1.0	0.0	3.6	0.0	6.3	5.5
Counseling service																	
Country total	30.4	36.7	60.6	37.8	16.7	39.6	48.8	22.6	6.2	5.3	16.0	11.9	9.4	8.0	16.1	39.4	23.6
Private urban schools	65.6	62.3	82.2	83.1	87.8	100.0	55.4	54.1	28.4	27.0	33.8	42.4	51.3	33.7	75.6	78.9	73.1
Public rural schools	39.2	45.5	59.8	35.4	22.1	51.7	63.7	25.0	11.9	5.4	24.7	23.3	10.8	7.9	12.2	45.6	11.6
Public rural schools	10.0	7.3	38.6	11.3	6.9	27.3	29.1	8.7	1.3	2.1	6.3	4.5	2.0	3.6	0.0	15.1	5.5
Sixth-grade school utilities (percentage of schools possessing utility)																	
Drinking water																	
Country total	80.9	82.7	91.1	79.9	86.4	94.2	93.0	61.1	67.7	82.4	81.2	60.0	61.9	65.1	67.4	65.8	98.1
Private urban schools	98.9	100.0	100.0	91.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.4	100.0	100.0	100.0	92.1	100.0
Public rural schools	92.0	93.8	89.6	89.9	92.8	99.0	100.0	81.5	98.7	94.4	94.8	93.8	100.0	86.2	91.0	72.6	100.0
Public rural schools	64.8	55.6	84.8	63.6	82.5	89.4	79.3	35.8	55.5	78.3	67.4	48.5	48.8	54.3	48.1	48.1	83.6
Drainage system																	
Country total	66.2	55.0	78.2	83.3	74.3	72.1	82.6	60.6	52.4	45.0	69.5	32.7	47.0	30.6	47.4	61.0	96.5
Private urban schools	91.0	78.8	86.5	95.6	100.0	100.0	97.7	87.6	91.7	100.0	100.0	89.8	100.0	79.6	92.3	97.6	96.2
Public rural schools	83.3	76.4	81.1	89.3	82.4	95.9	93.7	81.3	88.3	93.5	85.7	64.0	89.7	34.9	85.4	67.7	97.3
Public rural schools	42.6	9.3	61.4	69.9	68.5	48.1	56.5	40.0	38.1	30.8	51.7	17.2	30.5	21.2	18.5	37.9	92.7

(continued)

	Latin America	Argentina	Brazil	Colombia	Costa Rica	Cuba	Chile	Ecuador	El Salvador	Guatemala	Mexico	Nicaragua	Panama	Paraguay	Peru	Dominican Republic	Uruguay
Sufficient restrooms																	
Country total	68.5	75.1	83.3	65.0	59.1	90.8	89.8	54.9	66.5	49.7	66.0	34.9	49.8	60.0	51.8	73.4	81.4
Private urban schools	97.9	99.2	100.0	95.6	100.0	100.0	100.0	87.5	95.9	98.1	100.0	80.8	89.6	100.0	95.9	97.6	96.2
Public rural schools	75.4	75.0	81.4	64.6	68.6	89.8	90.2	54.6	75.7	56.2	74.2	56.3	84.6	62.7	68.0	59.3	76.1
Public rural schools	51.9	59.1	69.7	45.8	51.2	91.7	77.8	41.9	59.7	41.8	54.1	23.1	36.9	52.5	32.0	68.4	85.5
Electricity																	
Country total	91.5	95.8	100.0	94.4	96.4	99.5	99.4	97.4	94.4	74.6	96.7	59.1	66.7	89.3	59.0	86.0	99.6
Private urban schools	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.4	100.0	100.0	100.0	100.0	100.0
Public rural schools	98.8	100.0	100.0	98.0	98.3	100.0	100.0	100.0	100.0	96.3	98.1	95.0	100.0	96.1	96.4	89.7	100.0
Public rural schools	82.2	87.2	100.0	87.5	95.3	98.9	98.4	95.1	92.3	68.1	95.0	46.6	55.2	86.0	31.5	76.5	96.3
Telephone																	
Country total	53.3	72.5	79.1	70.6	75.4	35.7	85.1	45.4	48.0	18.3	41.0	28.4	34.0	23.8	30.0	44.9	98.6
Private urban schools	97.5	100.0	100.0	95.6	100.0	100.0	100.0	95.9	100.0	88.4	100.0	89.8	95.0	86.7	92.0	89.1	100.0
Public rural schools	75.7	95.3	87.5	80.1	89.4	65.0	100.0	51.2	97.3	48.7	65.4	59.2	88.6	49.1	45.0	61.3	99.5
Public rural schools	18.1	22.1	34.5	46.2	67.7	6.0	56.2	22.3	28.6	4.2	12.1	12.2	14.1	7.3	5.3	12.4	90.9

Annex 10.2. Omission rates for indicators by index and by type and ISEC status of school

Third grade sample schools						
Indexes	Total	Urban private	Urban public	Rural public	Quintile 1	Quintile 5
Sports area	4.4	3.8	3.9	4.9	4.4	3.4
Multipurpose areas	6.7	9.8	8.1	5.0	4.0	10.7
Office area	5.4	3.7	2.9	7.4	5.4	4.2
Academic area	7.1	8.7	9.0	5.4	4.6	9.3
Health area	7.0	5.9	11.3	4.7	4.4	6.9
Water and sanitation	4.3	2.0	3.8	5.2	4.6	3.0
Utilities	3.9	1.5	2.3	5.6	4.4	2.0

Sixth grade sample schools						
Indexes	Total	Urban private	Urban public	Rural public	Quintile 1	Quintile 5
Sports area	4.0	2.8	3.8	4.8	3.9	2.9
Multipurpose areas	7.1	6.9	8.7	5.8	3.2	6.7
Office area	4.5	3.2	3.7	5.9	3.1	3.1
Academic area	7.1	8.3	8.7	5.3	3.4	7.7
Health area	6.2	5.9	7.5	5.2	3.6	4.5
Water and sanitation	5.2	1.9	4.7	7.2	5.8	2.9
Utilities	4.9	1.9	2.9	7.9	5.7	2.5

Annex 10.3. Relationship between school infrastructure and learning in reading and mathematics for third grade in Latin America according to the SERCE study using the sample without imputation

	Reading				Mathematics			
	Rural schools		Urban schools		Rural schools		Urban schools	
	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC
Index	b/p	b/p	b/p	b/p	b/p	b/p	b/p	b/p
Sports area	2.07	1.52	-2.69*	0.39	4.87**	4.71**	-3.07**	-0.41
	.29	.43	.05	.74	.02	.03	.04	.77
Multipurpose area	2.32	2.46	4.72***	2.91***	0.16	0.2	4.37***	2.79**
	.43	.39	.00	.01	.96	.95	.00	.02
Office area	-4.26	-4.63	4.38**	0.14	-6.04*	-6.19*	-0.25	-3.79*
	.17	.13	.04	.94	.08	.07	.91	.08
Acadmic area	6.65**	5.80*	13.75***	6.42***	4.63	4.31	13.62***	7.26***
	.03	.06	.00	.00	.18	.22	.00	.00
Health area	0.19	0.57	7.10***	3.08***	0.37	0.49	6.89***	3.50***
	.96	.87	.00	.01	.93	.90	.00	.01
Water and sanitation	3.28	1.00	7.42***	-0.47	-1.05	-1.82	4.40*	-2.18
	.13	.64	.00	.82	.66	.45	.09	.37
Utilities	7.59***	1.61	7.64***	-2.71	3.02	1.03	4.25	-4.24*
	.00	.53	.00	.20	.24	.72	.10	.08
Socioeconomic status (ISEC)		15.59***		42.21***		5.24*		34.44***
		.00		.00		.09		.00
Public school				-19.04***				-18.46***
				.00				.00
Constant	478.50***	480.92***	493.95***	495.23***	483.75***	484.59***	493.17***	496.73***
	.00	.00	.00	.00	.00	.00	.00	.00
N	979		1179		1001		1176	

Note: Differences statistically significant at *10%, ** 5%, and *** 1%.

Annex 10.4. Relationship between school infrastructure and learning in reading and mathematics for sixth grade in Latin America According to the SERCE study using the sample without imputation

	Reading				Mathematics			
	Rural schools		Urban schools		Rural schools		Urban schools	
	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC	Without ISEC	With ISEC
Index	b/p	b/p	b/p	b/p	b/p	b/p	b/p	b/p
Sports area	3.82*	3.28*	-4.24***	-1.16	3.21	2.79	-0.72	1.8
	.06	.09	.00	.34	.17	.22	.67	.25
Multipurpose area	-3.90	-3.6	4.05***	2.08**	-6.62**	-6.53**	4.72***	3.12**
	.17	.19	.00	.04	.04	.04	.00	.02
Office area	-5.42	-5.52*	5.54**	0.29	-8.51**	-8.75**	1.99	-2.42
	.10	.09	.01	.88	.03	.02	.45	.32
Academic area	6.18**	4.96*	13.82***	6.19***	5.39	4.58	15.43***	8.93***
	.05	.10	.00	.00	.13	.19	.00	.00
Health area	5.59	5.85*	6.94***	2.13*	9.92**	10.23***	6.37***	2.48*
	.10	.08	.00	.06	.01	.01	.00	.09
Water and sanitation	6.68***	3.32	7.70***	-1.63	2.47	0.01	6.90**	-0.99
	.00	.14	.00	.44	.35	1.00	.02	.72
Utilities	10.75***	2.27	6.63**	-4.25*	9.25***	2.68	3.94	-5.15*
	.00	.40	.01	.06	.00	.40	.20	.08
Socioeconomic status (ISEC)		22.20***		46.30***		17.11***		38.91***
		.00		.00		.00		.00
Public school				-19.42***				-16.36***
				.00				.00
Constant	473.16***	480.00***	487.89***	498.18***	478.09***	483.28***	484.48***	493.25***
	.00	.00	.00	.00	.00	.00	.00	.00
N	802		1119		801		1112	

Note: Differences statistically significant at *10%, ** 5%, and *** 1%.

PART 6
Public-Private Partnerships to Build and Manage Schools

11

The Spanish Concessionary Model for Social Infrastructure and Public Facilities

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In Spain, the delivery, financing, and management through public-private partnerships (PPP) of infrastructure, facilities, and public services is regulated under the comprehensive Public Contracts Bill (*Ley de Contratos del Sector Público*—LCSP) and corresponding sectorial bills. However, other PPPs have a public asset base but a private legal status, such as operational leasing. PPPs that are based on concession contracts for public works or the delivery of public services are particularly noteworthy.

In the following pages, we will focus exclusively on infrastructure and public facilities necessary for contracted services. We will not be addressing the delivery of public services or services in the public interest that do not require the building of infrastructure or public public facilities either because they have already been built or are being negotiated, for instance, along with the use of private sector infrastructure.

Provision and financing of social infrastructure and public facilities through concessions in Spain

The Spanish concessionary model has taken on various contractual and non-contractual forms. These include:

- Public works and services concessions
- Concessions through mixed-economy corporations
- PPP contracts with competitive dialogue but structured as concession contracts
- The LCSP, a mixed contract form in which infrastructure can be financed through the granting of a public domain concession under the terms of legislation that regulates administration of cultural assets such as historic buildings.

Public works and services concessions

In most cases, the Spanish concessionary model is implemented through two different types of contracts: (i) the public works concession; and (ii) the public services concession involving public works.

It is important to distinguish public works concessions from contracts for the management of public services that involve building public works. In a contract for the management of public services, the public agency entrusts the contracting party with the management of a service, the delivery of which has been assumed under its jurisdiction by the granting agency. The grantor of a public works concession, on the other hand, can be a government agency or other public entity.

It is equally important to be clear as to whether the end user is the customer of the concessionaire or the agency. If the latter, we must consider who is paying for what:

- Payments by the user (with demand risk)
- Payments by the granting authority or another public or private entity
  - Per capita payments by the grantor (transfer of demand risk to the concessionaire)
  - Payments according to the quantity and quality of the services delivered by the concessionaire (transfer of availability risk to the concessionaire)
- Combination of payments made by the grantor (transfer of demand and availability risks to the concessionaire).

Distinctive characteristics of the public works concession contract

Spain's distinctive concessionary model cannot be separated from the nation's favorable environment for PPPs, which is set forth in one main law and related specialized legislation.

The concessionaire is granted the right to build and operate the project in order to provide public services or services in the public interest for a fixed period and at a given price. The demand and availability risks of construction, financing, and operation are transferred to the concessionaire even if they are partially mitigated.

The granting agency can stipulate that the concessionaire draw up the construction plans for the project, with the concessionaire assuming the risks of its proposals. Economic ownership of the work, while it is in operation, belongs to the concessionaire. Public spending is therefore not required. Legal ownership of the assets and the services, however, remains with the grantor; the public agency therefore retains financial liability.

The agency can include the construction of several works in the same contract if they share a functional relationship and fall under the jurisdiction of the same agency. The agency can also anticipate areas and works for complementary activities needed by the users of the concession.

The agency can contribute public resources to financing a concessionary work where there are social or economic profitability issues or unusual demands regarding public use or public interest. The construction of the work can also be financed through contributions from other public agencies or national and international bodies. The concessionaire can be required to subcontract at least 30% of the works. A project's economic and financial viability study and its preliminary plans or project plans must be made public in advance.

Concession bids can be initiated by private parties or by other agencies, as long as the bids are accompanied by a feasibility study. Bidding specifications must include, among other things: the award criteria; bidder requirements; rates; penalties and incentives for the quality of services; economic benefits such as financial benefits, tax benefits, contributions the granting authority or other authorities may offer; and a schedule of penalties and grounds for sequestration. Under the law's progress clause, services provided by the operator must be performed under conditions propitious for the advancement of science and technology. The bidders must commit to forming a company, according to specifications, and to take title of the concession.

Concessions must always be awarded by tender or negotiation but may be done in either an open or closed manner. The aim is to select the most efficient bidder from those that demonstrate sufficient financial and technical capacity and to prevent unqualified or otherwise undesirable bidders from winning.

Once the contract has been finalized, modifications are only permitted for reasons related to the public interest. Any such modification requires readjusting the financial plan. A substantial modification or a modification that exceeds the value of the work by 20% will give the concessionaire the right to rescind the contract.

The concessionaire's rights and obligations

The rights of the concessionaire include: the right to preserve economic balance within the concession, provided that the circumstances set forth in the LCSP are present; freedom from the threat of compulsory expropriation; the right to assign, mortgage, and securitize receivables with prior authorization from the granting agency; and the right to bonuses if the quality of the service exceeds the required standards.

The obligations of the concessionaire include: maintenance; ensuring safety in the absence of the authorities; fulfilling the progress clause; and meeting specific standards of service quality or facing penalties.

Privileges and prerogatives of the granting agency

The concession contract is conceived as a cooperative, symmetrical, and balanced contract that defends the interests of grantor, concessionaire, financier, subcontractors, and users. The agency has the power and duty to adjust the contract when necessary to maintain economic balance among the parties:

- In cases of *ius variandi*,[1] *factum principis*,[2] and *force majeure* by modifying any economically material clauses in the contract that limit its extension
- In cases where the contract itself establishes grounds for its revision
- In cases where contractual disputes are settled according to the law governing disputes involving private entities and public agencies. The concession contracts do not provide for arbitration.

The agency has the following rights and privileges, among others:

- To modify the public works for reasons of public interest
- To terminate the contract
- To impose penalties, which cannot exceed 10% of the budget for works still under construction or 20% of the previous year's operating revenue for works already in operation
- To impose fines if the concessionaire is continuously in breach of its obligations
- To take over the public work from the concessionaire, due to negligence on the part of the concessionaire or otherwise, for a period not to exceed three years unless contract is rescinded
- To impose operating conditions to resolve exceptional circumstances.

1. Decisions of the granting agency allowed by law.

2. *Factum principis* envisages modifications to the conditions of the contract due to an unforeseen circumstance that has an impact on the preservation of the economic balance of the contract (a typical example would be the closure of a port due to war).

Financing

Though the concession contract is conceived as the project's financing mechanism, public support can be used to guarantee its financial and economic viability (figure 11.1). Among other sources of financing, the concessionaire may:

- Issue obligations and other securities, backed by the state, that must be cashed in prior to the termination date of the concession
- Issue securities, with the prior authorization of the agency, that represent a share in the concessionaire's creditor rights
- Mortgage the concession with the prior authorization of the agency
- Take out equity loans.

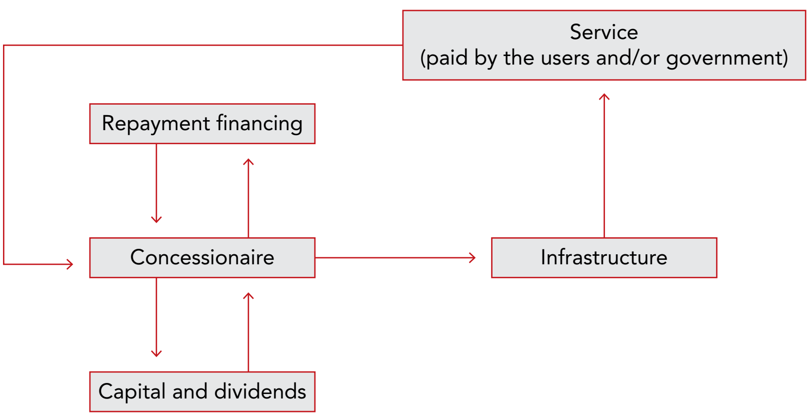
The mortgagor and holders of securities that represent concessionaire credit rights can exercise step-in-rights, allowing them (a) to request that the agency end concessionaire negligence or misconduct that could lead to damage or deterioration in the concession; and (b) to propose a replacement concessionaire or temporarily take over concessionaire obligations, as long as they can meet the requirements for doing so.

In the step-in clauses, the agency gives financial backers the tools to avoid incurring moral hazard, since it is recognized that the continued alignment of interests under the contract is advantageous for both parties.

Duration of the concession

Concessions generally dissolve after an agreed upon time-limit, which usually cannot exceed forty years. Grounds for earlier termination include (a) mutual agreement; (b) sequestration for more than three years; and (c) bailout due to reasons of public interest,

Figure 11.1. Simplified representation of concessionary financing



Source: Author.

in which case the agency is obligated to make payments on any unamortized investments, deducting any possible penalties. If concessionaire negligence is not a factor, the concessionaire must also be compensated for lost earnings based on the previous five years of results.

Strengths of the concessionary model

The extensive experience gained in the implementation of the Spanish concessionary model allows us to offer some conclusions with respect to its strengths and weaknesses.

The regulatory framework of the model is solid and has enabled all types of agencies to use the concessionary system. Between 2003 and 2010, according to data supplied by SEOPAN, the union associated with the major developers involved in concessions, some 500 projects were bid for, at an approximate value of €50 billion. This number represents approximately 13 percent of the total investments made in public facilities and infrastructure in Spain over this period.

The model has incorporated effectiveness and efficiency into the Mechanism for the Provision of Infrastructure and Public Facilities (Sistema de Provisión de Infraestructuras y Equipamientos Públicos). It has allowed for the bidding and contracting of concessions with relative ease, speed, transparency, and objectivity, seeking to ensure competitiveness and the selection of the best candidate. It also has helped achieve many of the objectives of the infrastructure policy and enabled the early completion of many projects, which in other circumstances would have taken many years, because the model provides incentives for beginning operations early in order to generate earnings more quickly.

The existence of the model has stimulated the creation of responsible companies, capable of managing public services and services in the public interest and that did not enter into contracts for opportunistic motives. It has allowed Spanish developers to gain experience in the area of concessions, several of which have grown in size and become multinationals. It has enabled the shareholders of the concessionary company, in effect the promoters of the investment, to avoid assuming the balance of the risks in a contract, which remain the responsibility of the company.

Until recently, it has avoided bidders resorting to risk reduction offered by the agency for the building and financing of concessions. Similarly, it has avoided the mitigation of demand risks that by law is offered to bidders.

Because the model requires feasibility studies in order to ensure project viability and bankability, concession projects have been financed for many years without any significant problems.

The existence of the agency's financial liability has made it easier to obtain project financing. The step-in clause facilitated financing through mortgages and the securitization of receivables. Investors value the fact that approximately 80% of a contract is set out in legislation and that the extent of the system of bonuses and penalties is known, as well as the conditions for early termination of the contract. The laws governing the model emphasize the notions of cooperation, balance, and symmetry, which are then reflected in contracts. The parties also value the known distribution of risks and the possibility, under certain circumstances, of rebalancing the contract that are offered under the law.

Finally, the model allows operations to benefit from the progress clause and quality indicators.

Weaknesses of the concessionary model

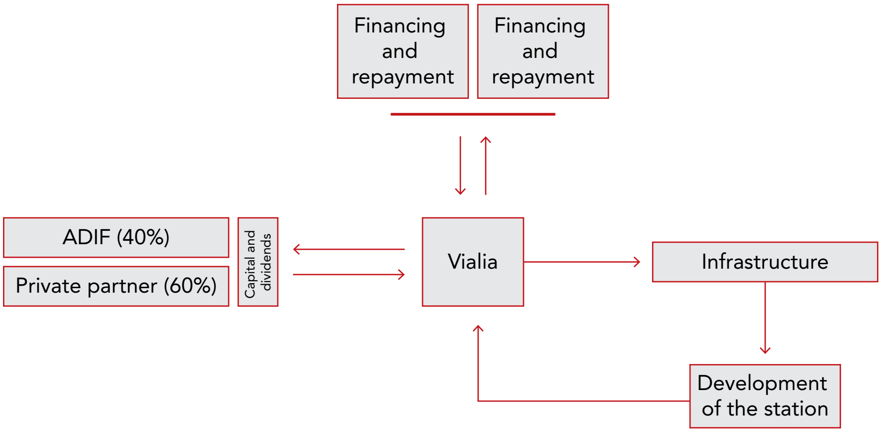
Although there is an overall sense that the Spanish concessionary system is operating well, the system has some weaknesses. Bidding specifications are sometimes poorly and hastily prepared, sometimes not setting high enough quality and solvency requirements for bidders. There is occasionally an excess of competition, and would-be concessionaires make excessively aggressive tenders, in many cases bordering on recklessness. This causes financing issues. Allegedly concessionary formulations sometimes actually allocate investment costs to public accounts due to the purported concessionary PPPs later being declared base companies. There is a lack of oversight of those in charge of public accounts in many regionally administered concessionary projects. The agency systematically avoids construction, financing, and demand risk mitigation. Recently, issues have arisen regarding the risk of expropriation of many concessions due to a change in the interpretation of the valuation rules in the Land Bill. Finally, some contracts are insufficiently specific with respect to quality requirements.

Concessions through mixed-economy corporations

Mixed-economy corporations offer significant PPP potential, whether they had the mixed-economy structure from their inception or became so by selling part of their shares to the private sector through public tender. (See figure 11.2 for an example of a mixed-economy corporation.) Companies that were of a mixed economy nature from their inception may be concessionaires, given that the winner of a concession may be required to form the concessionary corporation with a public partner in keeping with the contract's tender specifications

Public contracts can be awarded directly to mixed-economy corporations that combine public and private capital as long as the selection of the private partner is carried out in compliance with the rules established by the Public Sector Contracts Bill, and as long as the subject of the contract and its conditions, which were considered when selecting the private partner, have not been modified.

Figure 11.2. Public-private partnerships in the Vialia de Renfe program



Source: Author.

When selecting the private partner, the bidding specifications must define the relationship between the partner and the granting authority, between the granting authority and the mixed-capital corporation, and, in particular, between the public contract or concession to be awarded to the corporation and the bylaws regulating the latter. The specifications should also clearly and precisely set out the possibility of extending or modifying the public contract or the concession, along with a framework for new obligations under the contract, detailing the potential obligations and the conditions under which they would arise.

Public agencies can create entities to address public services or services in the public interest on a market basis. Some of these entities are not genuinely business units or do not entail enough risk for the investments to appear on their balance sheet. Their accounts are therefore merged with those of their parent agencies.

Public-private partnership contracts with competitive dialogue

PPP contracts are intended to resolve especially complex problems for which the corresponding agency lacks legal, economic, or technical solutions and therefore requires assistance from the private sector. This assistance is delivered through what is called "competitive dialogue." This consists of:

- Selecting candidates who meet the requirements and who wish to bid
- Initiating a dialogue between the granting authority and the selected candidates to develop one or several solutions that meet the needs in question
- Presenting bids based on the selected solution or solutions.

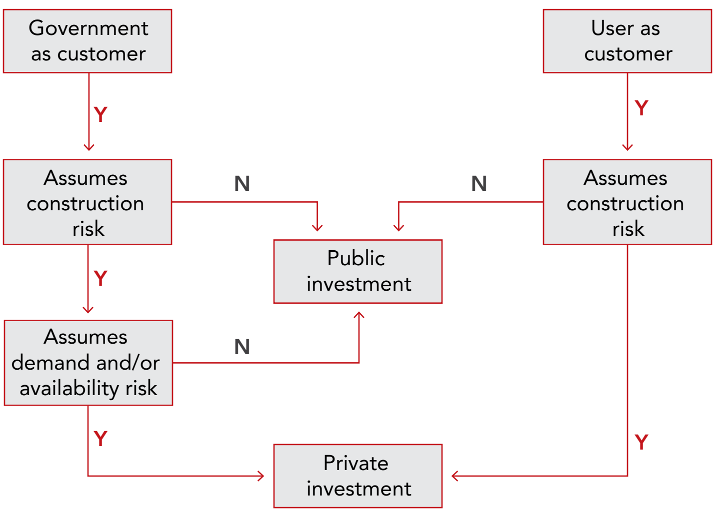
Spanish regulations restrict the use of competitive dialogue to contracts for partnerships, defined as contracts for participation between the public and private sectors in which the public agency, a public corporate entity, or a similar organization from the autonomous communities commissions a privately held entity for a period determined by the duration of the amortization of investments or the anticipated financing formulas to play an overall and integrated role. In addition to the financing of non-material investments, works, or the necessary inputs for fulfilling stated objectives related to public services or services of public interest, this role should include one the following features:

- Building, installing, or converting works, facilities, systems, products or complex goods, followed by maintaining, renovating, operating, and managing them
- Comprehensively managing complex facility maintenance
- Manufacturing goods and delivering services that incorporate technology specifically developed to provide more advanced and more profitable solutions than those already on the market
- Providing other services associated with the agency's development of public services or the general public interest entrusted to it.

Contracts for PPPs are permissible only when it has been previously demonstrated that alternative contracting options cannot duly satisfy public expectations.

The contractor may, under the terms set out in the contract, assume the supervision of the necessary works along with the complete or

Figure 11.3. Concessional investments in national accounting



Source: Author.

partial implementation of projects for their execution and for the contracting of specific services.

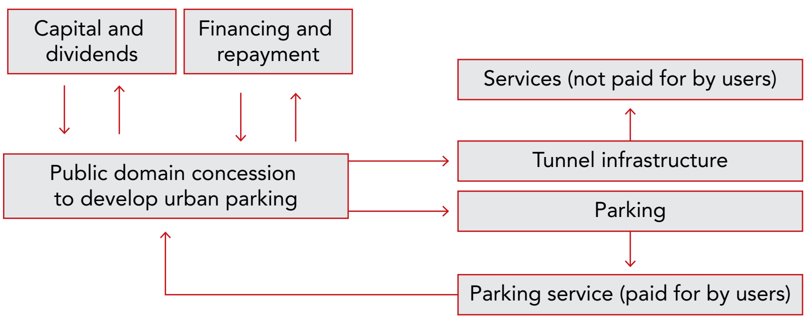
Compensation for the collaborating contractor will entail a price that will remain constant for the duration of the contract and that may be associated with meeting particular performance objectives.

In PPP contracts with competitive dialogue (CCPP), contracts that are not standardized, the private partner does not as a general rule assume the content of the contract at its own risk and responsibility but rather the content that is established in the contract that it transfers to itself. However, the LCSP stipulates that these contracts may be structured on the basis of any of the standard contracts, which is why one often encounters CCPPs configured on a concessionary basis.

Mixed contract with public domain concession

Mixed contracts make it possible to finance infrastructure in exchange for a public domain concession. This type of contract is often used for works such as ports or airports. It enables financing of the necessary infrastructure while offering the builders the exclusive option to operate part of the existing public domain or of an entity to be created in that form. An example of this form of contract appears in figure 11.4.

Figure 11.4. Example of financing using a mixed contract



Source: Author.

12

The Chilean Concessionary Model for Social Infrastructure and Public Facilities

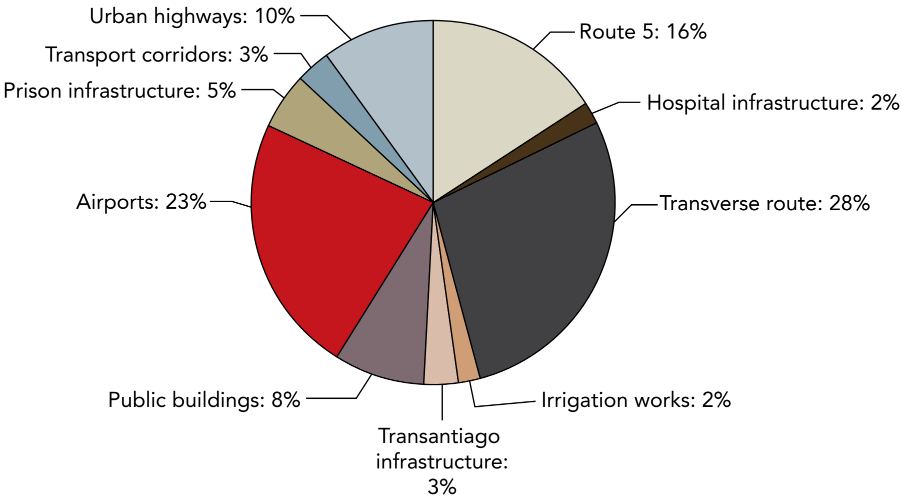
Miguel Angel Jara Muñoz, Industrial and Civil Engineer, University of Chile

Chile's concessionary system: A brief summary

Chile's concessionary system is based on experience gained from business models it has been developing since 1993. The nation has invited tenders for 65 concessions totaling more than $15 billion for a portfolio of projects in which the diversity of investments stands out (figure 12.1). One hundred twenty businesses worldwide have participated.

Two clearly identifiable stages in the promotion of concessionary mechanisms have emerged from this successful process. During the 1990s, efforts were focused on stimulating initial infrastructure concessions necessary for supporting national development, such as airports, arterial roads, and urban highways. Beginning in 2000, the portfolio was diversified into areas that support growth in the country's social and productive sectors, meeting the needs of government departments that saw the opportunity in the Concessionary Law of the Ministry of Public Works to implement needed projects like transport interchange stations, customs facilities, buildings for the overhaul of the criminal justice system, cultural centers, major recreation centers, irrigation reservoirs, prisons, and hospitals.

Figure 12.1. Diversity of tendered projects by number of projects



An ambitious program currently underway for 2010–14 aims at fostering private investment in public works and increasing private sector participation in concessionary initiatives.

The program, totaling more than $8 billion and extendable to $11.5 billion if projects currently under study are incorporated, aims to foster private investment in public works in order to facilitate national development, extend the reach of that investment to other areas of the economy, increase the quality and safety of investment mechanisms, and increase private sector participation in generating concessionary initiatives. Included in the program are several unique projects like community centers, urban parks, hospitals, and railroads.

This successful public-private partnership model has a number of strengths:

- A solid legal and regulatory framework that establishes the parties' rights and obligations and incorporates flexibility and creditor protection into long-term contracts
- Political backing, which lends stability to the long-term contracts
- Operational transparency, which bestows confidence on both the public and the private sectors
- High-quality projects and adequate distribution of risk among the various participants;
- Innovative financing structures incorporated into the contracts
- Backing and active development participation by government entities such as the Ministry of Finance (*Ministerio de Hacienda*), the Office of the Comptroller General (*Contraloría General de la República*), and the President of the Republic.

So far, $700 million worth of public works have been tendered under this model. Highlights of these projects include the Santiago Justice Center, the Plaza de la Ciudadanía, the Parque O'Higgins indoor stadium, and the dry port of Los Andes, as well as prison and hospital infrastructure.

Public construction through PPPs

To provide services that satisfy the needs of citizens, governments require public works that are designed and managed to adequate standards while preserving important pieces of the national heritage. Worldwide experience has demonstrated that a variety of Public-Private Partnerships (PPPs) can be used to address this demand. Under a PPP alliance, investment, costs, benefits and, above all, risks associated with project development are distributed among the state and private participants.

There are multiple alternative models within the PPP concept. The main categories of contracts are: design, build, operate, transfer (DBOT); build, operate, transfer (BOT); operate and transfer (OT); and lease, operate, transfer (LOT).

One advantage of the PPP system is that infrastructure projects can be carried out with long-term financing, overcoming the problem of having to prioritize investments within a limited budget. Additionally, each participant can evaluate its costs and decide whether to assume or transfer the associated risks; one of the main weaknesses of the public sector is the potential cost overruns it must assume as a result of inadequate risk management. A third advantage is the possibility of incorporating private management into a project, which can generally be more bold with respect to streamlining resources.

Development through a PPP alliance can ultimately prove more efficient. The private partner may have more experience operating in the relevant area of public construction and may be able to improve efficiency in areas that might have been overlooked by the public-sector partner.

The PPP model can generate significant benefits for a country without becoming a burden on end users. Rather, it can be supplemented with state financing deferred over the long-term, state property, or the efficient transfer of risk to the private sector.

However, in defining the structure of the concessionary model, one must consider the extent to which management of public infrastructure services is transferred to the private sector.

Choosing which type of contract to use depends on a series of factors, including the particular characteristics of the project, the degree of state control over the services covered by the concession, the level of flexibility the public entity wishes to maintain once the project has been handed over to private management, the magnitude of investments, and the period of time before the public authority is willing to hand the project over to private administration.

There are a variety of options for defining the extent of the concessionary contract. For instance, if the state wishes to move forward with a specific architectural design, responsibility can be transferred to the private sector for construction without allowing for the presentation of alternative designs. Alternatively, the government can transfer nonessential services, leaving the services directly associated with the infrastructure in the hands of the private entity. Chilean hospital grounds are one example of this method.

In cases where the private sector has more experience in the relevant services and building management, however, it may be better equipped to employ innovative and efficient designs. It will therefore be more efficient than the state in designing public infrastructure works that it will later operate. In these cases, it is advisable to transfer the design, building, and operation to the private sector.

PPPs and the education sector

This article has highlighted advantages and key considerations regarding the use of PPPs in the development of public construction projects. The PPP experience across a variety of sectors can be adapted to the specificities of the education sector. Worldwide, public-private involvement in education is nothing new and is quite extensive.

PPPs should therefore be explored as a potential tool to help control deficits and improve the development of educational infrastructure while maintaining state ownership and regulation. This is undoubtedly one of the main advantages of the model.

A second advantage is that the mechanism will free up resources so that the Ministry of Education can streamline investments, allowing for their use in other social sectors with fewer resources. With this model, for instance, investments can be brought forward so that more educational facilities can be built in the near term thanks to short-term financing obtained by private entities, while public contributions can be planned over the long term.

The contracts account for risk by incorporating catastrophic insurance, yielding substantial benefits in time and money for the fiscal authorities. This was evident in the damage suffered by Chilean concessions following the February 2010 earthquake.

Another clear advantage is the chance to conserve fiscal assets, since infrastructure maintenance is leased as a basic service, which is then clearly regulated.

In order to create a PPP model for education, clear definitions must be established for the description and extent of services, the indicators of minimum service levels permitted, and regulatory mechanisms. Some public building services will be standard, independent of the specific area of development being promoted, such as comprehensive maintenance and repair (infrastructure, standard equipment), janitorial services and garbage disposal, landscaping, maintenance of equipment food services, laundry services, safety and security, parking, signage, and communications.

Similarly, the model can define the extent to which infrastructure and services will be managed under the concession, ranging from the most basic aspects to the most complex, including implementing the educational model itself. In other words, the model can incorporate the provision of educational services to the desired degree of sophistication while incorporating requirements that allow results the be measured in a way that generates comparable management indicators. Therefore, the definition of other services will depend on the extent to which the state transfers management and operation to the private entity; that is, the degree to which the state cedes control to the private entity so that it can freely administer the infrastructure.

Once the extent of private management has been defined, it is important to establish regulatory elements, incorporating an evaluation system for service level indicators that will enable objective evaluation of compliance with the standards defined in the contract. To ensure success, it is always advisable to work with multi-sector participation and establish an action program, with the goal of fulfilling commitments within the context of a prioritized program.

Conclusions

The structure of the contract is central to PPP projects. Substantial effort must be invested in identifying and resolving risks in order to determine the implications of the services provided in the contract and of project financing, and to fully understand the interaction with private parties in the transaction, the business model, state guarantees, and interaction with technical teams, among other tasks.

Therefore, some of the aspects that should be taken into consideration when defining what type of contract to implement are as follows:

- The complexity of the proposed services and their relationship with infrastructure design and maintenance
- The infrastructure's intended function
- Architectural flexibility
- The extent to which management responsibility may be delegated to the private entity
- The availability of an objective evaluation model for services.

The PPP model has significant advantages from which Chile and other countries in the region can benefit. The model could be a crucial tool in the education sector for regional governments to meet their objectives.

13

The United Kingdom's Private Finance Initiative (PFI) and Building Schools for the Future (BSF)

Germán Millán, Director and Country Manager for Chile, Turner and Townsend Ltd.

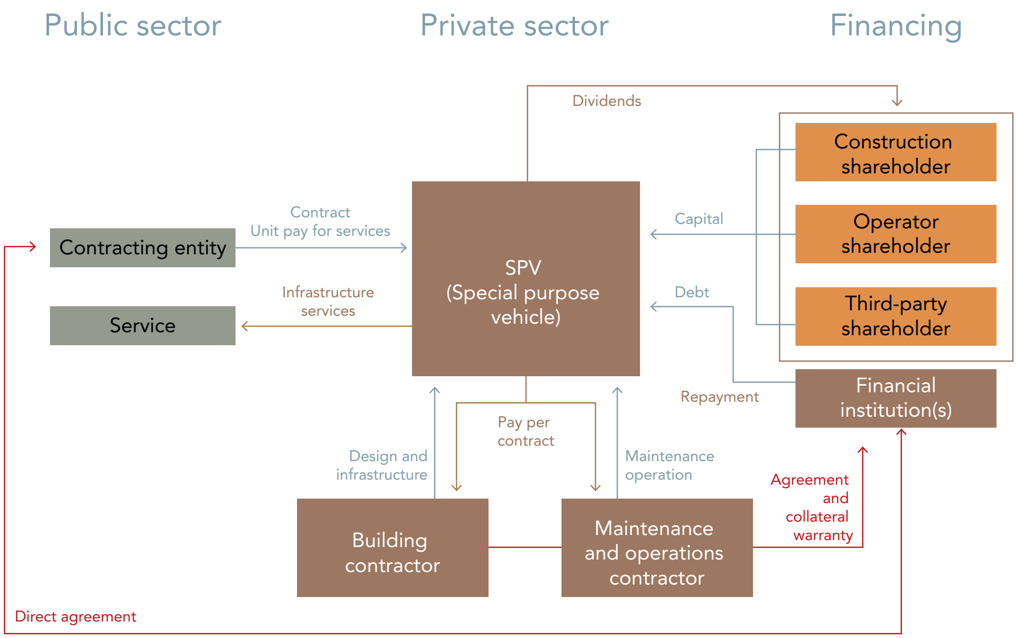
The British private finance initiative (PFI) is the world's most significant application of the public-private partnership (PPP) model to schools. The PFI was formally launched by Conservative prime minister John Major in 1992, but it was a Labour administration—namely, that of Tony Blair—that pushed it forward. The PFI emerged as low investment levels were stalling the construction of public infrastructure such as railroads and schools. The classic PFI model is illustrated in figure 13.1.

The PFI has become a global benchmark for public-private ventures. In Latin America, Mexico's service provision projects (SPPs) come closest to the British model.

In the United Kingdom—unlike in other countries, such as Chile, where PPPs have been concentrated in the transport sector—the PFI has been implemented in a variety of sectors. The model has not only been applied to infrastructure and services related to education, health, and justice but also to municipal services such as solid waste collection and treatment, energy, and public lighting.

In terms of volume, this model accounted for over 900 signed contracts (about 700 of which were operational in 2010) and capital investment amounting to more than $110 billion by the end of 2009. Transportation projects—most of them quite large—accounted for 67 of the 900 contracts but as much as 36.6 percent of total investment.

Figure 13.1. The "classic" PFI contract structure



In education, by contrast, 225 projects accounted for only 13.9 percent of total investment. The majority of projects are widely dispersed and quite small—often a single school per contract—though a few school infrastructure construction projects are among the largest in the history of PFIs. Even the larger projects started out small and evolved to their current size.

The use of PFI contracts peaked in 2007 and 2008. During this period, the British government made a net investment of £29.4 billion in the public sector. Private investment in public services via PPPs was nearly £4.5 billion during the same period, or 15 percent of total investment (a substantial jump from 11 percent in 2003–04).

It is clear from this that the PPP model, even in the country where it has been most used, is just one tool among many at the public sector's disposal for developing infrastructure.

Evolution of educational models

In the United Kingdom the PFI was applied to a series of small pilot projects in individual schools for an initial period, starting from 1997. From the beginning, it was thought that each PFI would be measured in terms of output, or results. In practice, however, the emphasis was placed on input, or supplies. The goal was to reduce costs and improve operational components such as availability, space, cleanliness, maintenance, and other activities directly related to the daily operations of a school.

An RFP (request for proposals, or call for tenders) process was also established during this period. Meanwhile, the traditional PFI model grew quite rapidly, to some 25 projects between 2003 and 2008.

Alongside this growth came the need to measure various factors, including value for money, life-cycle costs, and facility management costs. A new sector of industry developed—one that went beyond construction to encompass the management and maintenance of public buildings.

The general consensus was that the PFI model had improved quality, mainly as a result of the appropriate distribution of risks. A report from the National Auditor in 2003, however, noted that value for money was significantly worse in PFI schools than in schools financed through traditional methods. Defenders of the PFI argued that the calculation used to estimate value for money was unnecessarily complex and not scientific.

After the initial years, the traditional PFI model was retained but its elements were increasingly standardized. The UK ministry of finance noted that because small projects offer no benefits of scale, such operations must grow in size before time and cost efficiencies can be achieved. As a result, schools started to be grouped into categories by geography, size, or type (elementary, middle, and special education). Important efforts were made to standardize school design, for example, through the promulgation of Building Bulletin 98, which provides space specifications for public schools. Likewise, performance specifications were standardized, as were key contractual documents. The ministry of education now provides guidelines, while the municipalities—which are the educational authorities at the regional level—have standardized their procedures to streamline, accelerate, and shorten bidding terms; reduce the stress involved in preparing bidding documents; and clarify how projects are to be run, thereby increasing the transparency of the entire process.

Meanwhile, increasing attention is being paid to excellence in design. PFI projects had been accused of being merely functional entities with no architectural presence in their neighborhoods. Design quality indicators (DQIs) were drawn up to address this issue.

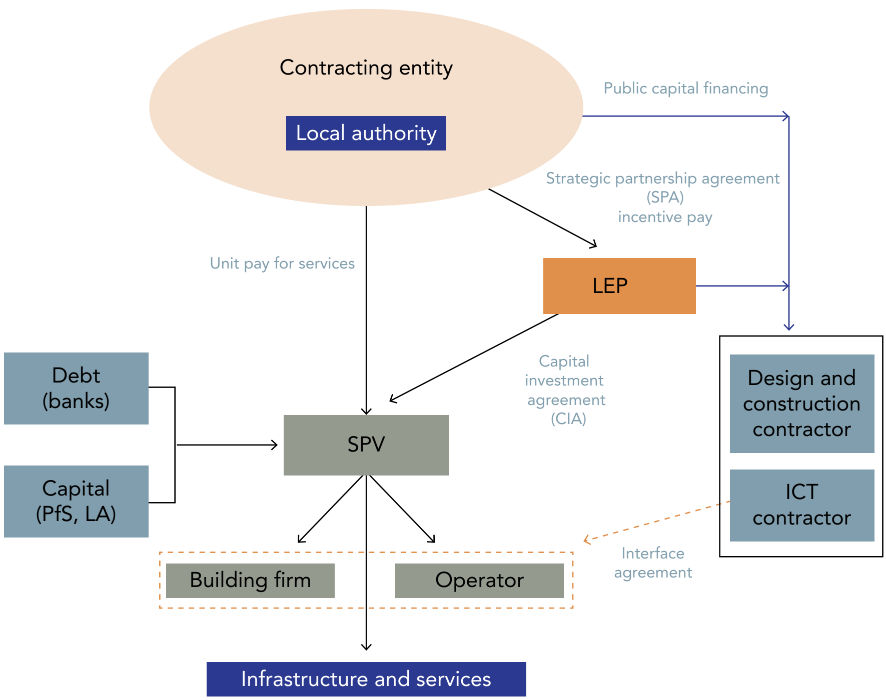
All of these initiatives contributed to growing project sizes, in turn making project operations more attractive to the private sector. Economies of scale in the government sector—in particular, the human resources available for preparing bidding processes and requests for approval—became better matched to projects.

In 2004 the central government launched the Building Schools for the Future (BSF) model with one simple, though ambitious, objective: to rehabilitate or rebuild all of the junior high schools in the United Kingdom by 2015. The estimated investment was around £50 billion (approximately $80 billion). This model differed from the PFI model in that a joint venture known as the Local Educational Partner (LEP) was created between the public and the private sector, with an 80 percent private share and a 20 percent public share in the project (10 percent each from the central government and the municipalities involved).

The history of PPP models in the schools sector does not end with the BSF. This was a starting point from which other associated models emerged, including the Academy Program and the Capital Investment Program, which were directed at focused needs such as special education. Not all of these involved joint public-private investments; some consisted of capital investments from public works that complemented the BSF model.

What value is added by the BSF model? The left side of figure 13.2 presents a simplified version of the traditional PFI model. The LEP has been added, creating a dual contract. One of the components is the PFI, and the other is a strategic partnership with a group (shown on the right-hand side of the figure) that assumes the functions traditionally carried out by the local public educational authority. Given the type of services provided, such a group is very similar to a consulting or outsourcing agency. The LEP

Figure 13.2. The BSF model: The PFI plus a new group (the LEP) assuming the functions of the local public educational authority



contracts are generally for 10 years, in contrast to the 25-year PFI contracts. Their primary objective is to support the municipality in the development of a comprehensive infrastructure building program for high schools. For example, other complementary works are included aside from the PFI, such as information technology systems providers, public works, special schools, and urban regeneration works associated with the construction of schools, acting as a means to integrate the municipality's real estate portfolio.

The BSF model

What are the key components of the BSF model? From supplies to space to maintenance, this model represents a third level of PPP development, one with a greater emphasis on results. But the difference is due to a gradual progression, not a quantum leap. In the first stages, construction and building systems and better support services are specified. Later, the PPP is linked to performance levels among students and teachers.

This model thus combines the traditional, public works PFI with changes to the bargaining process and a more competitive dialogue resulting from regulations from the headquarters of the European Union in Brussels. In the early years, the PFI involved a bargaining process consisting of prequalification followed by a traditional bid, at the end of which two bidders were selected. The selected bidders then made an improved final offer, resulting in negotiation with the preferred bidder. But this was not what the European Union (EU) wanted.

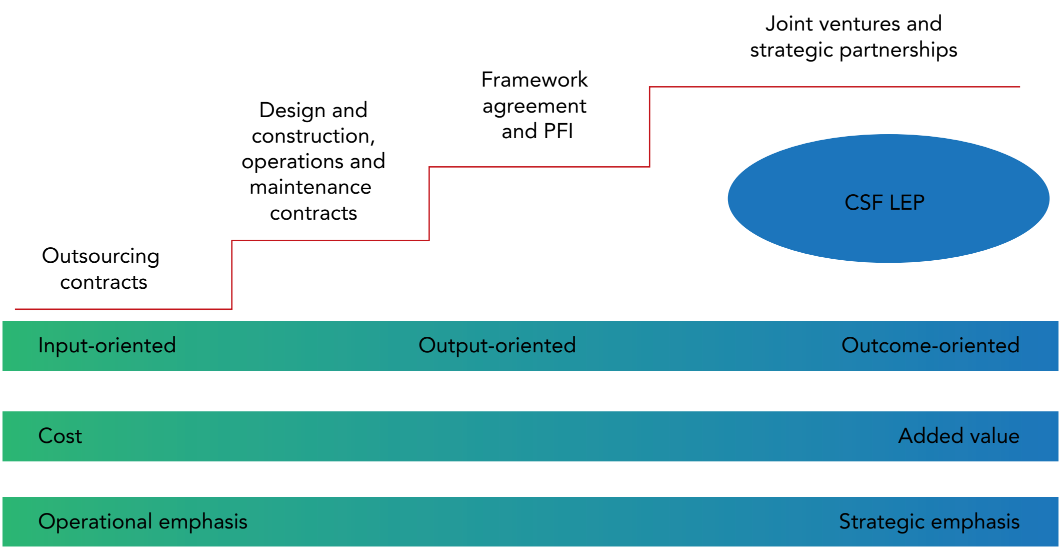
So a third option was created, somewhere between the negotiated process and the restricted process. (The negotiated process was limited to English-speaking countries while the restricted process was limited to Mediterranean Europe.) The third option uses the BSF and, since 2006, the PFIs as well. This consists in a negotiated process followed by a restricted process—it is a hybrid creation. In the initial phase, there is a series of subphases in which the number of bidders is reduced from around eight to six, then four, and finally two. In this process, which begins with prequalification, everything is up for discussion, including prices. By the time when such dialogue comes to a close, there are normally only two bidders left. After this, the bidding becomes a restricted process, with all the rigorous procedures found in Latin American contract bidding. The objective is to reduce the time spent: although the costs increase, the risks are reduced.

The fundamental characteristic of the BSF process is its emphasis on added value and the use of a development strategy (figure 13.3). In order to do its job, the LEP must be closely involved in the strategic work conducted by the corresponding municipality. Without this strategic link, there can be no transformation—and the transformation of education is at the core of the investment program. The new emphasis is on educational change through the use of better services, spaces suited to twenty-first century pedagogy, and information and communication technologies (ICTs) appropriate to needs.

What are the most important changes that have taken place since the implementation of all of these processes? Since 2006, the government has placed major emphasis on the standardization of the competitive dialogue. An agreement was made to conclude the preparation and approval of the works before starting the bidding process and to further standardize bidding documents. Without central leadership, the municipalities could spend years on each bid, and therefore the government's ambitious 10-year program could not be fulfilled, especially the Partnership for Schools program, which pioneered this standardization.

The key change is that the BSF standardization uses the change strategy. The initial approval the municipality must obtain from the central government is related to the pedagogical objectives of the program for a specific portfolio of schools and as part of the municipality's vision for a given year and geographical environment. There must be a link between actions and expected outcomes. There are also political issues such as authorization from parliament for the investment and consultation with students and teachers over investment priorities. The project-selection process emphasizes democracy and transparency as well as optimal use of information technologies. The LEP must understand the education arena and have professional and pedagogical capacities in excess of those of an ordinary actor .

Figure 13.3. Joint ventures and strategic associations under the BSF model, contrasted with earlier models



Other important issues deal with prequalification processes—namely, how they can be expedited and made more efficient, thereby simplifying the bidding process. In 2009 the longest bidding process took 80 weeks and a PFI could even take up to three years.

In short, there has been an evolution from outsourcing public works such as maintenance, security, and construction to contracting design, construction, operation, and maintenance. Later came traditional PFI contracts and then strategic partnerships and joint ventures. The emphasis has shifted from inputs to outputs and a focus on outcomes. At the same time, there has been a change in focus from cost assessment to measuring the overall value of learning. There has also been a shift from an operational vision to a strategic one through the project approval and implementation processes.

Difficulties

But the road has not been easy; criticism of the privatization of education has been recurring. In terms of expected outcomes from the BSF, the government tried to transfer the risks to the private sector. Only some of the partners were prepared to accept those risks, however, since their experience was in infrastructure and not education. The government tried to use academic performance as a management indicator for LEPs. But the municipalities put an end to this trend: they were the ones that suffered the consequences if academic indicators began to deteriorate. The Office of School Inspectors can now intervene if the LEP does not fulfill the indicators.

Several indicators have been incorporated into the LEP and not transferred to the PFI, however. Among these are retention of personnel and students, greater confidence among parents, better student behavior, student satisfaction, number of students in extracurricular activities, and extra hours.

Vision for the future

Currently, the public investment program with the greatest promise is one parallel to the BSF known as the Academy Program for technical or industrial schools. Most of the schools involved are large ones with multiple educational or financial problems; most already have some private investment in their operation and curricular design. The government grants these schools a license to operate independently of the municipal structure and to define an academic program different from the one provided by the municipality, which allows them to collaborate with industry in training the future workforce. The private educators typically have a relationship with industry. In case of irregularities, the regulatory body can step in and revoke the license.

In the British case, with the advent of the global economic crisis and in the face of high public debt, David Cameron's Conservative government decided to cancel the BSF program but to continue with the Academy Program. The perceived benefit of the Academy Program was that it decentralized decision making by providing vouchers, or a direct subsidy system, through which parents could decide where to send their children, thus creating competition between education providers. The intention was to bring the British model closer to the Scandinavian model, in which private schools receive a direct subsidy.

In this context, the Academy model makes more sense, in that a private partner and an industrial partner define priorities and the curriculum (ostensibly in competition with other providers of public education), the goal being to help young people find employment when they complete high school. But the new plan makes less sense in the context of an educational curriculum organization that is more centralized and guided by urban planning, such as that pursued by the Labour government over the past 13 years.

Key factors to consider

Transformation. The transformation encouraged by the BSF model consists of movement toward change, using PFI models as triggers. The curriculum must go from rigid to flexible and the learning mode from passive individual in-school learning to active, community-based, and group learning. The school must go from single use to multiple uses and become the center of the community, something that has been lost in modern societies. The development of secondary education is linked to the educational development of adults, continuous education, neighborhood committees, and social services. This transformation can be achieved by a more sophisticated PPP model (such as the BSF or the Academy Program), but not through a basic or initial PPP model such as the traditional PFI.

Information technology. It is essential to incorporate ICTs into the investment program so as to optimize the use of physical space. For example, with proper planning, cables and wires can take up less space, and provisions can be made for fixed technology such as projectors and smart boards. Planning for ICT use in advance also allows savings on telephony and other operations and systems in a building, such as security and the library. Most important of all, ICTs add flexibility to the pedagogical process (allowing teachers to move from left to right in figure 13.4). Without flexible designs that allow for the long-term involvement of IT service providers, flexible solutions cannot be reached.

But technology should change not only infrastructure but also teachers and their pedagogy—that is, technology should impact teaching and learning. Links with families

Figure 13.4. From tradition to transformation under Britain's Academy Program

Maintain Tradition	Initiate Change	Progress	Clear Vision of the Future	Transformation
Rigid curriculum	→	→	→	Flexible curriculum
Standardized education	→	→	→	Personalized education
Individualized learning	→	→	→	Collaborative learning
Teacher-centered	→	→	→	Student-centered
Passive learning	→	→	→	Active learning
Learning (alone) in school	→	→	→	Learning in communities
Subject-based structure	→	→	→	Relations-based structure
Isolated	→	→	→	Integrated
Used only by students	→	→	→	Shared (community) use
Single use	→	→	→	Multiple uses
Highly specialized facilities	→	→	→	Flexible facilities
Single pedagogical model	→	→	→	Multiple models
Tradition-based	→	→	→	Research-based
Hierarchical decision making	→	→	→	Horizontal decision making

and the community must also improve if both want to be part of this change, which makes the school the center of the local community.

In addition, the design of the schools could also be improved. By placing ICT at the center of the design, safe, attractive, and functional facilities can be created. ICT provides support for a small-school culture, promoting individual development and innovation and moving away from the institutional schools of the nineteenth and early twentieth centuries.

Conclusion

In sum, it should be stressed that an initial reference model exists, namely the traditional PFI, but that it has evolved considerably since its inception. Today, we talk about many models that have the capacity to progress and adapt to the various realities and sectors of public life. Several submodels have also arisen over time—after the traditional PFI came the DBFO for highways, LIFT for primary health care, Scottish Future Trusts, and P21 for hospitals.

In education, specifically, the PFI was followed by the BSF, the Capital Program (PCP), and the Academy Program. We have also discussed other issues, including educational transformation and ICTs. Because of the ongoing economic crisis, conditions are changing rapidly and the political context makes the Academy Program the best choice for now.

Latin America can learn from the experience and errors of Great Britain. At present, Mexico is the regional leader for testing similar paths but in its own way and context.

It is always necessary to place a pedagogical strategy at the center of public policy action. Much damage can occur when a PPP concession project is used as a development method for overambitious projects undertaken for political reasons. PPP projects must instead be put at the service of pedagogical transformation or used for improving school conditions, and these priorities must in turn be felt at the center of the community.

14

The Mexican Experience and Recommendations for Public Infrastructure Development and Financing through Public-Private Partnerships

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This paper examines public-private partnerships (PPP) for infrastructure projects in Mexico at the federal, state, and municipal levels, emphasizing the importance of capital markets in the projects' long-term financing, especially in the construction phase.

Context

Mexico has a GDP of over $950 billion and a population of more than 108 million. Standard & Poor's rates the country as BBB on a global scale. This is the agency's lowest rating for "stable investments" and denotes "medium class borrowers, satisfactory at the moment of classification." Recently, Mexico issued a $1 billion bond due in 100 years, which represents something of a new paradigm for Latin America. In 2010, the Ministry of Finance and Public Credit (*Secretaría de Hacienda y Crédito Público*) emphasized that this represents "the biggest placement on record, due in 100 years, making Mexico the

1. The author thanks Mauricio Gutiérrez De Gregori for his comments and ideas.

Table 14.1. Comparative infrastructure indicators for Mexico and high-income countries

Indicators	Mexico	Medium- and high-income countries	OECD Average
GNP per capita, Atlas method (current US$)	7,870	6,612	33,470
Percentage of population with access to electricity	-	84	-
Electric power consumption (kWh per capita)	1,660	2,566	8,769
Percentage of population with accessed to an improved water source	97	92	99
Percentage of population with access to improved sanitation facilities	79	84	-
Total telephone subscribers per 100 inhabitants	62	85	-

Source: World Bank PPIAF (2009).

first Latin American country to issue paper with this maturity and the second sovereign nation to do so (China issued US$1 billion in 1996, with a 9% yield)." This indicates international confidence in Mexico's stability and potential.

Nevertheless, the country has room to improve in the areas of infrastructure development and the delivery of quality public services if it wants to meet the demands of society while maintaining healthy government finances and stable macroeconomic indicators. Table 14.1 illustrates the relative situation of the country in an international context.

The economic crises of the 1970s and 1980s caused a shift in Mexico's economic policies, resulting in a series of privatizations and the liberalization of various sectors and culminating in the signing of a free trade agreement with the United States and Canada (North American Free Trade Agreement, or NAFTA). The nation then passed a series of laws to implement NAFTA's provisions, affecting diverse sectors of infrastructure. However, this liberalization failed for several reasons and the country fell into a deep financial crisis accompanied by double-digit inflation and a currency devaluation of over 200%. The government was forced to intervene to support various sectors, such as banking and toll roads. The international recession at the end of 2008 and its impact on Mexico in 2009 then compelled the Mexican government to establish a legal, financial, and technical framework for private sector participation in the development of infrastructure and the delivery of public services through PPPs. Given the complex context of the 1990s (notably the peso crisis that began in 1994), PPP development has varied according to the needs of each sector (Ramos 2010).

Table 14.2. 2007–12 National infrastructure program: Project totals by primary sector and subsector (US$ million)

Sector	Subsector	Number of projects	Total investment
Energy	Electrical	22	7.9
	Natural gas	27	2.8
	Energy total	49	10.7
Telecommunications	Telecommunications	14	54.0
	Total	14	54.0
Transportation	Airports	6	3.2
	Railroads	7	4.5
	Highways	53	16.8
	Ports	22	0.7
	Total	88	25.3
Water and Sewage	Treatment plants	24	1.4
	Water	5	0.2
	Total	29	1.6
Total		180	91.8

Source: World Bank PPIAF (2009).

Hence the 2007–12 National Infrastructure Program (*Programa Nacional de Infraestructura*) was created, with projects focusing mainly on water, roads and highways, oil and gas, energy, telecommunications, transportation, essential services delivery, and environmental cleanup and hazardous material disposal (table 14.2). As part of the program the federal government formed the National Infrastructure Fund (*Fondo Nacional de Infraestructura*—FONADIN), financed primarily by the Infrastructure Investment Fund (*Fondo de Inversión para Infraestructura*—FINFRA), which was created during the 1990s as part of the highway bailout program (FARAC).

Framework for federal PPPs

One of the most important strategies for achieving economic growth is to increase the quantity and quality of private and public capital and services.[2] Public infrastructure and associated economic and social services require particular attention within public

2. While economists have maintained for decades that the public capital stock is an important input in the overall production of countries, this relationship had not been formally analyzed prior to the work done by Aschauer (1989a, 1989b). Important contributions to the question have recently been made by Agénor and Moreno-Dodson (2006).

policy. Given the high level of financing required to develop public infrastructure and the limited resources that can be derived from alternative uses, the public sector needs resources that will help it to prioritize investments and choose contract models. Thus, as indicated in the 2007–12 National Infrastructure Program, public resources alone are insufficient to substantially increase the coverage and quality of infrastructure. Mexico must therefore encourage better private-sector financing of infrastructure investments while selecting the best alternatives for implementing each project.

Private-sector participation in the design, financing, construction, maintenance, and operation of public infrastructure has grown in Mexico and many other countries over the last twenty years, taking on different conceptual and legal configurations. The following table illustrates the evolution of the private sector in several productive infrastructure sectors from 1990 to 2009.

To complement previous investments, in 2005 the Mexican private sector began to participate in a variety of ways in social and governmental infrastructure projects, such as specialized regional hospitals, universities, rehabilitation and social reintegration centers (*Centros de Rehabilitación y Reinserción Social*—CERESOS), and public building projects.

Private participation has taken on a variety of forms. Firstly, it has consisted of concessions to operate a public service or capitalize on public assets in sectors such as highways, ports, telecommunications, water, airports, railroad, and hydraulics.

Secondly, the private sector has participated through Productive Long-Term Infrastructure Projects (*Proyectos de Inversión Diferida en el Registro del Gasto*—PIDIREGAS), which emerged in 1995 as a provisional mechanism through which project development was entrusted to private sector businesses able to secure the necessary investments for public entities. Since 2005 two versions of this program have emerged:

- Direct investment, in which, due to the nature of the contracts, the entities assume the obligation of acquiring productive assets built to their specifications.
- Contingent investment, in which the acquisition of physical assets is not the principal objective of the contract. However, an obligation to acquire the assets may arise as a consequence of default or *force majeure*, as outlined in a goods and services contract.

The model can also be divided into two investment schemes: (i) an independent producer option, where the contractor secures all of the investments required by the project and then runs the project, and (ii) financed public work, where the contractor secures all of the investments required to build the project and then, on completion, liquidates the secured investments, thereby directly acquiring the long-term financing that will allow the investor to pay for the works (Ramos 2010).

A third form of private-sector participation is the long-term service contract, useful when necessary infrastructure must be developed before a particular service can be delivered. The contracts include a budgetary commitment for specified years for services that will be provided in those years.

Another option is Projects for the Provision of Services (*Proyectos de Prestación de Servicios*—PPS), a 2005 scheme whereby a private investor, known as the investor-supplier, makes a long-term commitment to provide services to public entities so that they can provide services themselves or better fulfill their obligations. In exchange, the public entities must periodically compensate the investor-supplier depending on the quantity and quality of the services provided.

Finally, in November of 2009, the President of Mexico put a decree before the Senate, which led to the passing of the Public-Private Partnerships Bill[3] and the amendment or repeal of several provisions of the Public Works and Related Services Bill, namely the Acquisitions, Leasing, and Public Sector Services Bill, the Expropriation Bill, the Farming Bill, the General Bill of National Assets, and the Federal Code of Civil Procedure (Ramos 2010).

According to the explanatory statement in the decree, the following were among the reasons given for supporting the proposal:

- The growth rate of a country's infrastructure is a crucial element in social development, the fight against poverty, and the well-being of the population.
- Although the country has existing mechanisms such as direct public works and public works contracted under the PPS and PIDIREGAS concessionary systems, high demographic growth and financial pressures have made it necessary to put new mechanisms into place that will allow the private and social sectors at all three levels of government (federal, state, and municipal) to increase their capacity for developing infrastructure through PPP schemes or additional variations, which differ from: (i) service contracts regulated by the Acquisitions, Leasing, and Public Sector Services Bill and involving not only the delivery of a service but also building the infrastructure to provide the service, and (ii) contracts for works regulated by the Public Works and Related Services Bill, given that PPP contracts cover service delivery but not the construction of fixed assets (infrastructure) themselves.
- PPP models aim to procure an equitable transfer of risk between the public and private sectors, converting the latter into a service provider for the federal public administration, with the indirect obligation of building the necessary infrastructure needed to provide the services, if required.

3. On October 12, 2010, the Senate passed the Public-Private Partnerships Bill, which opened up practically all sectors and services to private investment, including electricity, health, and education.

- With a view to proposing a flexible legal framework, the initiative stipulates that the infrastructure, if it is needed for service provision, either be executed entirely or partially by the private sector or be provided by the public sector.
- The proposed PPPs differ both from the schemes regulated by the Acquisitions, Leasing, and Public Sector Services Bill as well as from those included in the Public Works and Related Services Bill because they cover not only the delivery of services but also the implementation of the infrastructure needed to provide these services without the principle objective of the contract being the construction of fixed assets (infrastructure).

Article 2 of the bill defines PPP projects as any scheme in which the public and private sectors establish a long-term contractual relationship to provide one or more services to the public sector or end user, and in which infrastructures required for the provision of these services, whether it be developed totally or partially by the private or the public sectors. In order to fulfill this aim, the following steps are required: (i) enter into a long-term contract establishing the rights and obligations of the contracting public and private entities, and (ii) when necessary, grant one or more licenses, concessions, or authorizations for the use and operation of public assets, the delivery of corresponding services, or both.

PPP framework at the state and municipal levels

In Mexico, the responsibility for providing public infrastructure and services has traditionally fallen on the federal government. These projects have been financed directly through public spending. However, in recent years, as part of an important gradual process of decentralization, states and municipalities have had to finance a portion of this spending from their own resources. Mexico is made up of 31 states plus Mexico City. In 1994, the federal government was responsible for 73% of public spending, with the remaining 27% the responsibility of the states and municipalities. A decade later, 63% of spending was in the hands of the states and municipalities and only 37% in the hands of the federal government. Currently, the figure is close to 50%.[4] However, in the evolving federal fiscal structure, the increase in spending faced by the states and municipalities was not counterbalanced through increased capacity to generate revenue.

In recent years, federal entities have developed legal and institutional schemes to take advantage of the benefits offered by PPP models, and in particular PPS models, to attract private participation in the investment and management of infrastructure. The hope is that these plans will lead to efficient use of resources and better investment projects.

4. National Citizens Budget (*Presupuesto federativo ciudadano*, 2010).

The selection of projects is particularly important. This must take place under strict principles of cost-benefit analysis, prudent public finance criteria, and an assurance of widespread political and social support. Since PPP contracts last 15 or more years, it is essential that they enjoy ample consensus from all social participants. The better the project selection, the greater chance that the project will be successful.

In this regard, the Multilateral Investment Fund (Fondo Multilateral de Inversiones – FOMIN) of the Inter-American Development Bank has implemented the Program to Promote Public-Private Partnerships in Mexican States (Programa para el Impulso de Asociaciones Público-Privadas en Estados Mexicanos – PIAPPEM), which aims to improve competitiveness in Mexican states by using PPP schemes to promote public service and infrastructure expansion and improvement. The goal is to strengthen the legal and institutional capacities of state governments with the object of initiating harmonized PPP schemes, thereby increasing private participation in the expansion and operation of infrastructure and public services at the local level.

Similarly, in April 2010, FOMIN, as the executing agency of the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), launched the Municipality Strengthening for Public-Private Partnership Development Program (MuniAPP). The goal of this program is to promote a new culture for the development of public works and the delivery of services among Mexican municipalities, resulting in the expansion and improvement of these services through PPP schemes. Using a sustainable institutional platform consisting of a combination of on-site and information and communications technologies, the program will promote PPPs through: (i) training and development of technical skills, and (ii) technical, institutional, and legal assistance for Mexican municipalities in order to promote, plan, structure, and supervise local infrastructure and public services projects through PPP schemes.

Table 14.3 illustrates the current regulatory framework for the implementation of PPP schemes, and in particular PPS plans, in different states.

Financing of infrastructure and services: The importance of long-term institutional investors

Bearing in mind the experience of Chile, where a significant number of concessions were financed through the infrastructure bond market (or market financing) and through pension funds and life insurance companies, Mexico has a high availability of private assets that could be channeled through institutional funds. Indeed, the market for PPP project financing consists of institutional investors with significant and growing long-term liabilities, such as pension and insurance plans, which require similar-term assets to make their liabilities and assets match.

Table 14.3. Regulatory framework for PPP schemes in Mexico, by state

State	Current legal framework	Year
Aguascalientes	Law on Projects for the Provision of Services in the State of Aguascalientes	2007
	Regulations Governing the Law on Projects for the Provision of Services in the State of Aguascalientes	2008
Baja California	Law on Public-Private Partnership Projects in the State of Baja California	2009
Chiapas	Law on Projects for the Provision of Services in the State of Chiapas	2007
	Law on Service Concessions and Public Infrastructure in the State of Chiapas	2007
	Regulations Governing the Law on Projects for the Provision of Services in the State of Chiapas	2007
Coahuila	Law on Projects for the Provision of Services in the Free and Sovereign State of Coahuila de Zaragoza	2007
	Law on Acquisitions, Leasing, and Service Contracts in the State of Coahuila de Zaragoza	2009
Mexico City	Guidelines for the Elaboration of Cost-Benefit Analysis for Long-term Service Projects and annexes	2008
Durango	Law on Projects for Infrastructure and the Provision of Services in the State of Durango	2006
Mexico State	Financial Code for the State of Mexico and its Municipalities	2007
	Administrative Code of the State of Mexico	2009
Guanajuato	Law on Service Concessions and Public Infrastructure in the State of Guanajuato	2009
	Law on Projects for the Provision of Services in the State and Municipalities of Guanajuato	2010
Jalisco	Law on Projects for Infrastructure and the Provision of Services in the State of Jalisco and its Municipalities	2008
	Regulations Governing the Law on Projects for Infrastructure and the Provision of Services in the State of Jalisco and its Municipalities	2008
Michoacán	Law on Projects for the Provision of Services in the State of Michoacán de Ocampo and its Municipalities	2007
Morelos	Law on Public-Private Partnership Contracts in the State of Morelos	2008
Nayarit	Law on Public-Private Partnerships in the State of Nayarit	2006
Nuevo León	Law on Public-Private Partnerships in the State of Nuevo León	2010
Oaxaca	Acquisitions, Leasing, and Services Law for the State of Oaxaca	2008
Puebla	Budget, Accounting, and Public Spending Law	2007
Querétaro	Law on Projects for Investment and the Provision of Services in the State of Querétaro	2008

(continued)

State	Current legal framework	Year
Sonora	Law on Public-Private Partnership Services in the State of Sonora	2008
	Regulations Governing the Law on Public-Private Partnership Services in the State of Sonora	2008
Tabasco	Law on Projects for the Provision of Services in the State of Tabasco and its Municipalities	2007
	Regulations Governing the Law on Projects for the Provision of Services in the State of Tabasco and its Municipalities	2009
Tamaulipas	Law on Public-Private Partnerships for the Provision of Services in the State of Tamaulipas	2009
Veracruz	Law on Projects for the Provision of Services in the State of Veracruz de Ignacio de La Llave	2007
Yucatán	Law on Projects for the Provision of Services in the State of Yucatán	2009
Zacatecas	Public Administration Law for the State of Zacatecas	2007

Source: PIAPPEM (2010).

The principal long-term institutional investors in Mexico are: (i) retirement funds (*Administradoras de Fondos para el Retiro*—AFOREs), (ii) insurance companies (mainly life insurance), and (iii) annuity companies.

Retirement funds

The Mexican retirement fund system is made up of 17 entities that jointly administer 1.15 trillion pesos[5] at market value, distributed among more than 39 million accounts, with an average real return of 6.7% between 1998 and December 2009. The average growth rate of these resources was 31.5% for the same period.

The retirement funds were divided in a relatively equitable way among the participating companies, avoiding excessive concentration of funds among a few entities. The AFOREs with the most shares by value of their investment portfolios are Banamex (17%), Bancomer (16%), and ING (13%).

The AFOREs invest worker resources in different savings alternatives, segregating investments in a number of mutual funds known as SIEFOREs (*Sociedad de Inversión Especializada en Fondos para el Retiro*) according to the contributors' age. A SIEFORE is an investment fund specializing in retirement savings. It is a legal vehicle in which workers' resources are deposited in order to be invested in a predetermined securities portfolio.

5. In this section, values are expressed in Mexican pesos rather than U.S. dollars. The exchange rate on October 20, 2010, was 12.45 pesos to 1 U.S. dollar.

The investment portfolio of each SIEFORE consists of government securities, private bonds, foreign securities, national and foreign equity-based instruments, and CFE, PEMEX, and state and municipal securities. There is a particularly high share of government securities (66.3%). This could decrease over time in favor of private securities as the AFOREs seek greater profitability.

Insurers

In September 2009, the combined investments of the insurance sector rose to 447.6 billion pesos, which represents real annual growth of 9% relative to the previous year. The investment in securities represented 95.2% of the total investment and reached 426.1 billion pesos. The insurance market is led by Metlife México, which in September 2009 had a 32% market share, followed by BBVA Bancomer, with 13%, and Grupo Provincial, with 10%. Together, these entities own more than half of the market (Gutiérrez De Gregori 2010).

According to 2009 National Insurance and Sureties Commission (*Comisión Nacional de Seguros y Fianzas*—CNSF) regulations, a company can invest up to 40% of its portfolio in private debt securities, which include PPP debt issuances.

Insurers' investments are characterized by being very long-term, as almost half of the securities portfolio from September of 2009 was invested at terms of over ten years. In terms of risk, as with the AFOREs, preference is given to government securities offering the lowest degree of risk and the highest liquidity.

Annuities

The third and last segment of long-term institutional investment consists of pension fund companies that receive assets from the AFOREs when a worker retires and is guaranteed a pension for the rest of his or her life: hence the term "life annuity."

In September 2009, the investment portfolio in life annuity securities rose to 116 billion pesos, an unprecedented figure in the system's history.

Feasibility of long-term financing

AFOREs. Given the significant size of the accumulated funds and the high credit quality of PPP securities (AA or AAA), the regulations establishing investment percentage limits become irrelevant and the investment choices of each AFORE take precedence. The only limit applied in practice is the issue limit, according to which an AFORE cannot acquire more than 20% of an issue since an issue dedicated exclusively to the AFOREs requires a minimum of five AFOREs to complete the total issuance amount (Gutiérrez De Gregori 2010).

Insurance companies and annuities. Both types of investors are limited to having 40% of their portfolios in private securities, which includes PPP financing. In September 2009, insurance company and annuity portfolios reached 20% private securities. Insurers have the potential to acquire up to an additional 170 billion pesos in private securities, while annuities could invest up to an additional 23 billion pesos.

This potential does not take into account the future replacement of PPP securities with other private securities or the natural yearly growth of portfolios, which amounts to real annual growth of over 10%. Institutional investors are under constant pressure to show increased profitability. PPP market financing, which can achieve a high credit rating, offers the investor a better risk-return ratio since it is more profitable than government securities but has a similar level of risk.

This is the main reason for the significant potential for financing PPPs through the stock market; investors need—and constantly seek—higher profitability without increased risk (Gutiérrez De Gregori 2010).

Conclusions and recommendations

In order for the legal and regulatory frameworks that are being implemented at national and state levels to be useful and in order for the institutional funds to take advantage of the available resources, the following conditions are necessary: (i) the public sector must identify, evaluate, and prepare projects structured according to strict bankability criteria; and (ii) the required financing should be secured with high priority from the beginning, that is through payments in the construction stage funded through the issuance of stock.

There are a variety of market financing experiences currently underway at the international level that address this second condition. In Latin America, Chile has been a paradigmatic case. This has been primarily due to the participation of bond insurers and multilateral agencies that granted financial guarantees to projects in order to mitigate, above all, risks associated with construction, thus reaching the necessary credit ratings to be able to access the market.

According to Gutiérrez De Gregori (2010), the traditionally implemented format has been the following:

- Structure project risk in order to achieve a lower medium grade rating (BBB-) on a global scale. To achieve this rating, construction risks are mitigated with guarantees by the builder and the sponsor and, if necessary, with third-party liquid guarantees or *contingent equity* from the sponsor.
- Contract a *full wrap* financial guarantee, which covers the entire issue (as opposed to partial guarantees), with a monoline insurance company ranked AAA on a global scale.

- On the strength of this guarantee, since it is unconditional, irrevocable, and for the total amount, the guarantor's AAA is passed on to the stock issue and investors can acquire the issue since construction risks as well as all of the project-issue risks are assumed by the guarantor. (The investors only assume risks directly if the guarantor fails.)

Before the 2008 financial crisis, there were seven financial insurers with AAA ratings on a global scale (MBIA, AMBAC, FGIC, XLCA, CDC, FSA, and AG), several of which had made solid incursions into Mexico. In the years prior to the crisis, as a result of industry-wide competition, almost all of these entities had broken into new sectors, among them the mortgage sector, where they guaranteed issues backed by mortgages. When the crisis emerged, there was an unexpected rise in mortgage defaults, which made it impossible for these highly leveraged businesses to cover anticipated losses in their assets and that, in turn, led to a generalized and unprecedented fall in the credit ratings of monolines.

According to Gutiérrez De Gregori (2010), once divested of the AAA rating that had allowed them to sell their financial guarantees, the majority of these entities were no longer viable and practically ceased to exist, or they divided their businesses, concentrating exclusively on the North American municipal sector (the lowest-risk sector). To date, of the seven monolines6 that existed worldwide, only one, Assured Guarantee, continues to have a high credit rating that enables it to continue offering guarantees in the United States as well as internationally.

As a result, access to market financing for PPP projects under construction, which had been feasible thanks to the monolines, is no longer available. This, along with the instability and increased conservatism of the banks, has created a serious scarcity of financing for PPP projects.

With the virtual disappearance of the monolines, some options have appeared that will eventually allow access to market financing for PPP projects in the construction phase, though this has yet to be confirmed through transactions:

- Multilateral agencies, such as IDB, IFC, CAF, and OPIC have activated their offer of financial guarantees. However, most of them offer partial guarantees only, which cannot entirely mitigate construction risks for an institutional investor because these guarantees are limited to a specific amount.
- BANOBRAS and FONADIN offer partial guarantees, similar to those offered by multilateral agencies.

6. Insurance companies with a single line (monoline) of guarantees.

In light of this and given the importance of access to market financing for the success of PPP programs, it is likely that any measures the federal government may take to increase the offer of financial guarantees (diversity and availability of *full wrap* guarantees) will have a significant impact on the development of infrastructure through PPPs. The existence of effective financing options is a determining factor in securing the participation of major international infrastructure developers that up to now have essentially been absent from the Mexican market, generating increased competitiveness and lowering the level of government expenditure and/or user fees for infrastructure and services.

An interesting example to explore is the CRPAO model (CRPAO stands for *certificado de reconocimiento de avance por obras*) that has been successfully employed in Peru and could easily be extended to Mexico. The main advantage of the model is that it diminishes negative cumulative interest. Negative cumulative interest is produced because bonds must be issued for the total of the investment whereas the funds are accessed as needed over time. Consequently, interest accumulates on unused resources. Under CRPAO, bonds are issued only as needed to advance the works.

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15

The Carulla Foundation and the aeioTU *Initiative in Colombia*

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The Carulla Foundation, through its *aeioTU* initiative, has become one of the most important agents of social change in Colombia. *aeioTU* is the Carulla Foundation's only project, and it is exclusively focused on integrating education, nutrition, and care into early childhood. The photos throughout this chapter illustrate its activities (figures 15.1–15.5)

The Carulla Foundation has focused on the education sector since its founding in 1961. It initially offered scholarships to thousands of low-income employees of Carulla supermarkets and later Carulla Vivero, Inc. The foundation's achievements in this first stage reaffirmed its commitment to working in the education field. However, after taking note of the most recent studies on early childhood education and the low coverage and quality of services available to this vulnerable segment of the population, the Carulla Foundation decided to strategically refocus in order to achieve greater social impact and a higher return on investment. It created *aeioTU* in 2008 to provide quality comprehensive early childhood care with the aim of transforming Colombia by developing the potential of its youngest children. The Carulla Foundation has conceived itself as a "social company," and has introduced business practices that improve management and increase the impact of investment resources while using market forces to remain sustainable.

Table 15.1. At the end of 2010, aeioTU operated six centers in Colombia

City	Name of center	Enrollment	Capacity	Date of founding
Bogotá	Nogal	82	82	Jan. 2009
	Orquídeas de Suba	432	500	Feb. 2009
	La Estrella	289	300	Dec. 2009
Sopó	Gimnasio Campestre Alpina	91	93	Feb. 2010
Barranquilla	La Playa	313	312	Feb. 2009
Santa Marta	El Libertador	131	152	Mar. 2009
Total		**1,334**	**1,439**	

In addition to the first six a*eioTU* centers (table 15.1), there is a service center located in Bogotá, which consists of five directors (executive, pedagogy, finances, administration and partnerships, and communications) supported by a group of 12 professionals. The service center supports the *aeioTU* centers, defining organizational strategies and evaluating and adjusting the business model. It also manages purchasing, logistics, monitoring, hiring, and security.

Figure 15.1. Science project in aeioTU Orquídeas de Suba (Bogotá)

Table 15.2. Six new aeioTU centers opened in 2011

City	Name (and type) of center	Enrollment	Capacity	Month opened
Bogotá	Parque Nogal (A)	57	120	January
	Pasadena (B)	11	100	December
Carmen de Bolívar	El Salado (C)	79	120	September
Medellín	Aures (C)	—	352	February
	12 de Octubre (C)	—	352	June
Santa Marta	La Paz (C)	307	315	May

— Data not available.

Five new centers opened in 2011, doubling the current coverage (table 15.2).

The Carulla Foundation's experience with the *aeioTU* initiative shows that it is possible to provide quality comprehensive care to at-risk children. Several factors contribute to the quality of our service:

- A strong adult–child ratio
- Full-day care
- Provision of 90% of children's nutritional needs
- A high level of teacher training
- Artists-in-residence at each center
- Specialized environments and furnishings to foster child development.

Role of *aeioTU* in the management and financing of the education sector

aeioTU's multifaceted role is intended to improve the quality of comprehensive early childhood care, improve the administrative and financial management of early childhood organizations, and foster public-private partnerships to make strategic social investments.

The Carulla Foundation's strategy is based on its objectives and its vision of the role public institutions and private and social entities should play in early childhood development. In the foundation's view, the state is responsible for establishing public policy guidelines and standards of care, overseeing quality assurance, and financing alternatives that meet requirements. The private and social sectors, meanwhile, must run early childhood care centers that meet the requirements set out by the state. The Carulla Foundation is determined to establish *aeioTU* as an efficient enterprise of the highest quality.

Figure 15.2. A playful experiment at aeioTU La Plaza

From a pedagogical perspective, *aeioTU* seeks to institute an innovative, high quality project that sets the standard for early childhood education in Latin America. It has also set out to create better early childhood opportunities for at-risk families through a strategy of inclusion and improved access.

From an administrative and financial perspective, aeioTU seeks to establish best practice models for the private sector early childhood development industry in order to strengthen management structures, improve efficiency, and lower costs. It also seeks to create a cluster of highly specialized and qualified contractors, regulators, providers, and public and private donors. This will maximize the social impact of the project, increasing productivity, reduce costs, attract more investors, and stimulate local economic growth.

To this end, we have defined a differentiated strategy for market penetration that prevents excessive dependence on a single donor and takes advantage of emerging market opportunities. The expansion strategy hinges on the development of three types of center:

Type A center. Located in the wealthiest areas of Bogotá, these centers meet the needs of the most affluent segment of the population. This group's high expectations and *aeioTU*'s emphasis on a quality educational experience justify paying a premium, which in turn generates profits that are then reinvested in Type C centers. In the future, these centers will become major contributors to meeting service center administrative costs and subsidizing children from low-income families. Other cities with the potential to host this type of center are Medellín, Cali, and Cartagena.

Type B center. These centers meet the needs of the middle class. Given the high demand at this socioeconomic level and the financial viability of this business model, Type B centers will allow for the social franchising of *aeioTU* centers through social entrepreneurs, who will in turn form part of the *aeioTU* network. This type of center will only be put into operation once the Carulla Foundation has established an easily replicable, cost effective, standardized business model.

Table 15.3. Current Partners of aeioTU

Public sector	Private and social sectors
National Ministry of Education	Alpina
Municipalities of Bogotá, Barranquilla, Santa Marta, and Sopó	Mepal
Instituto Colombiano de Bienestar Familiar (ICBF)	Fundación Pies Descalzos
	Fundación John Ramírez Morno
	Fundación Éxito
	Fundación Saldarriaga Concha
	Sociedad Salesiana
	Jacobs Foundation
	Fundación AVINA

Type C center. Located in socially and economically at-risk urban areas, these *aeioTU* centers operate thanks to contributions from national and local government as well as partners from the social and private sectors. But even funds allocated by the National Education Ministry (*Ministerio de Educación Nacional, MEN*) through the Early Childhood Comprehensive Care Program (*Programa de Atención Integral a la Primer Infancia, PAIPI*) do not form part of the general redistributive mechanism and are not legally guaranteed, leaving early childhood care a question of political will. Due to the insufficiency of public funds, private contributions are crucial to reaching the almost two million children who currently live in extreme poverty and who do not receive any service that fosters their physical, cognitive, communicational, or socio-emotional development.

Figure 15.3. Light table at aeioTU Orquídeas de Suba (Bogotá)

Through its role as a catalyst for public-private partnerships, the Carulla Foundation works intensely to create and consolidate

Figure 15.4. Light and shadow corner at aeioTU Gimnasio Campestre Alpina (Sopó)

partnerships with public, private, and social entities (see current partners in table 15.3). The principal objective of these partnerships is to obtain, administer, and channel resources to guarantee high quality, efficient service. The partnerships range from the financing of a Type C center, as in the case of municipalities, the Ministry of Education, or the dairy producer Alpina, to improving the quality of our pedagogical project, as in the case of the Saldarriaga Concha Foundation.

The Carulla Foundation is also carrying out advocacy work by organizing academic events on key topics in early childhood development, with prestigious invited guests such as Carla Rinaldi (president of Reggio Children International) and Steven Barnett (codirector of the National Institute for Early Education Research at Rutgers University). In addition, the foundation aims to use technology and science to influence public policy and the early childhood agenda at the national and local levels. The foundation is using tools such as across-the-board studies to measure the effects of *aeioTU* on children's learning capacity, nutritional health, and cognitive, social, and emotional development. This study is led by Rutgers University in association with the Universidad de Los Andes and Harvard University, and enjoys the support of the IDB and the Jacobs Foundation. The results of this study will determine the efficacy and the cost-benefit balance of the investment in early childhood.

All of these actions stem from our support for early childhood education with the objective, as stated above, of developing children's full potential in order to transform Colombian society.

Figure 15.5. Toys at aeioTU La Estrella (Bogotá)

16

New Strategies for Supporting Municipalities in Mexico and Latin America

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This chapter outlines general information on public-private partnerships (PPPs), their relationship to the education sector, and some examples of their ties to corporate social responsibility. Such partnerships provide opportunities for new forms of cooperation between the public and the private sectors.

In today's economy, the financial resources available to the public sector are insufficient to provide society with the infrastructure and services necessary for its overall development. In view of these difficulties, new frameworks have been developed to tap into the financial capabilities, efficiency, and innovation of the private sector.

These frameworks for the delivery of infrastructure and services are known generically as public-private partnerships, or PPPs. Ideally, such partnerships unite and reinforce the strengths of the private sector alongside those of the government to achieve efficiency, effectiveness, and timeliness in infrastructure and public services delivery.

Characteristics of public-private partnerships

The term *public-private partnership* originated in the United States with the financing of joint education programs shared between the public and private sectors (Hinojosa 2007). In the 1950s, its use was extended to the development of other public services.

Additionally, the term is used in the United States to refer to social service programs offered by the nonprofit sector, and is applied to the public financing of private research and development (R&D) programs in the field of technology (Link 2006).

In the context of international development, the term is used to refer to joint initiatives of the public sector, international aid and development agencies, and the private sector, with aims such as to fight global diseases (AIDS and malaria, for example), to modernize the agricultural sector, and to promote overall economic development.

The PPP concept covers a variety of structures, including concessions, contracts, businesses, and trusts, each with its own particular configuration (figure 16.1).

Experts agree that PPPs use private incentives to improve the availability and efficient use of public resources through association with private sector incentives. They help channel these resources to projects important to human development, in large part by taking advantage of the experience and technical capabilities of the private sector. Another major advantage of PPPs is that risks are shared among the parties involved, thus enabling the delivery of infrastructure and quality services despite limited financial resources. Finally, PPPs can lead to increased competitiveness, which has an impact on regional development.

Figure 16.1 Specific models of public-private partnerships

Concessions	◆ Public services ◆ Public infrastructure
Contracts	◆ Turn-key operation ◆ Build-lease-transfer ◆ Build-operate-transfer ◆ Build-operate ◆ Design-finance-build-operate ◆ Capacity and electric energy purchase agreement ◆ Partnership or participation agreement ◆ Long-term delivery of essential services (among others)
Businesses	◆ Public with private minority interest ◆ Private with public minority interest
Trusts	◆ Public with private participation ◆ Private with public participation

Source: Compiled by the author based on data from ITESM (2010).

Creating a favorable environment for public-private partnerships

At the international level, the most advanced PPP experience is the private finance initiative (PFI) in the United Kingdom (Hinojosa 2007 and chapter 13 in this volume). This initiative has had a major impact on the education sector, as described below, as well as in the health sector, where a significant number of PPP contracts have been implemented.

International experiences such as the United Kingdom's are valuable in that they allow us to observe how PPPs must be adapted to individual country contexts, taking into consideration factors such as:

- Political and legal structures
- Market composition
- Political and economic climate
- Windows of opportunity.

In order for a public-private partnership to succeed, several elements must be in place, including a legal and regulatory framework, institutional policies, operational maturity, a favorable investment climate, and financial facilities. All of these elements are defined and identified in what the Inter-American Development Bank (IDB) refers to as its "PPP Index," which it publishes periodically and which lists the environment for PPPs in each Latin American country (table 16.1).

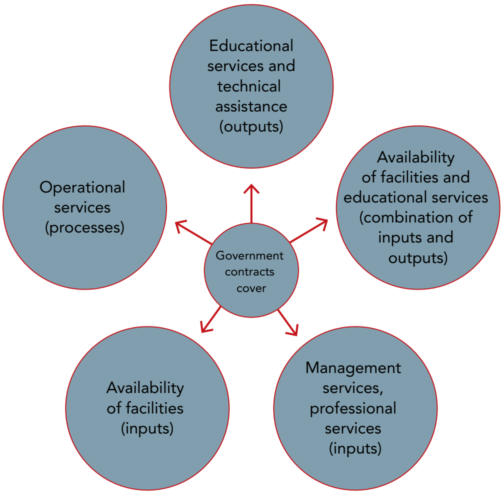
Table 16.1. Results of the PPP Index

Ranking	Country	2009 Score
1	Chile	64.3
2	Peru	58.9
3	Brazil	57.8
4	Mexico	47.5
5	Costa Rica	45.1
6	Colombia	39.1
7	Uruguay	27.3
8	Dominican Republic	25.2
9	Jamaica	25.1
10	El Salvador	23.9
11	Honduras	23.7
12	Trinidad and Tobago	22.9
13	Paraguay	22.3
14	Argentina	21.9
15	Panama	21.0
16	Guatemala	18.0
17	Ecuador	14.5
18	Nicaragua	10.0
19	Venezuela	7.1

Source: Economist Intelligence Unit (2009).

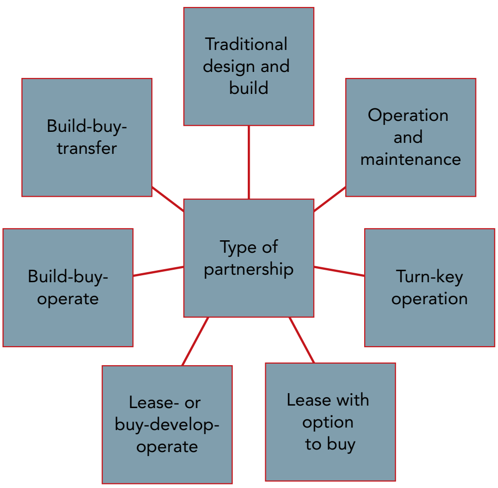
Additionally, it is important to consider the development of human and social capital through human resources training, technical assistance, and the development of experts who contribute— along with the factors in the "PPP Index"—to the creation of new models for the development of infrastructure and services. This is the focus of the Diploma in Public-Private Partnerships in Infrastructure and Services (Diplomado en Asociaciones Público-Privadas en Infraestructura y Servicios, DAPPIS), described below.

Figure 16.2. Types of contracts in education



Source: Compiled by the author based on Patrinos (2006).

Figure 16.3. Level of private sector participation in infrastructure: alternatives



Source: Compiled by the author on the basis of data from Patrinos (2006).

PPPs in the education sector

In the education sector, which faces significant infrastructure deficiencies throughout Latin America, there is a trend toward the use of PPPs to support and improve both quality and outputs. Benefits include improvements in the coverage, quality, and performance of public services; the possibility of ties with the productive sector; and potential savings (Patrinos 2006). A good example, as mentioned above, is the case of the United Kingdom, where in 1997 Tony Blair's Labour Party government developed an ambitious program for educational transformation in 3,000 secondary schools, with a projected investment of $100 billion over 15 years (Hinojosa 2007). The private sector was invited to carry out educational infrastructure reforms and provide services on a long-term basis by selecting the highest-priority schools on the basis of academic results and poverty indicators.

The British PFI has since been expanded significantly and applied to other sectors of the economy in the United Kingdom, including more than 800 long-term contracts for the delivery of public services through hospitals, schools, public buildings, prisons, and roads.

With respect to PPP schemes and possibilities in public education, Patrinos (2006) makes reference to the types of associations and contract models in the Latin American education sector. Figures 16.2 and 16.3 illustrate the type and level of contracts in education, which are explained and analyzed in tables 16.2 and 16.3, respectively.

Table 16.2. Types of contracts in education

What government contracts cover	Definition	Types of contracts
Educational services and technical assistance (outputs)	The government purchases available places for students in private schools (contracts for the enrollment of specific students). Purchase of technical assistance services to promote and encourage public sector policies.	Educational services contracts for specific students as well as training and technical assistance contracts.
Availability of facilities and educational services (combination of inputs and outputs)	The government purchases the available facilities combined with services (operational, or as outputs).	Infrastructure service provision contracts with educational services contracts.
Management services, professional services (inputs)	The government purchases school management services or professional and ancillary services.	Management services contracts, professional services contracts (curriculum design).
Availability of facilities (inputs)	The government purchases the available facilities.	Infrastructure service provision contracts.
Operations services (processes)	The government purchases school operations services.	Operational contracts.

Source: Patrinos (2006).

Table 16.3. Level of private sector participation in infrastructure: alternatives

Type of partnership	Characteristics
Traditional design and build	The government contracts a private partner to design and build facilities according to specific criteria.
Operation and maintenance	The government contracts a private partner to operate a facility that belongs to the state.
Turnkey operation	The government provides financing; the private partner designs, builds, and operates a facility for a specified period of time; and the public partner retains ownership of the facility.
Lease with option to buy	The private partner leases a facility from the government for a specified period of time; the property is then transferred to the government.
Lease- or buy-develop-operate	The private partner leases or buys a facility from the government; the private partner develops and operates the facility by means of a contract with the government for a specified period of time.
Build-buy-transfer	The private partner acquires an exclusive franchise to finance, build, operate, maintain, administer, and charge users during a fixed period of time to recover the cost of the investment; at the end of the franchise period, the property title is handed over to the public authority.
Build-buy-operate	The government transfers the ownership and responsibility of an existing facility, or contracts a private partner to build, purchase, and operate a new facility perpetually.

Source: Patrinos (2006).

Table 16.4. Contract models in the Latin American education sector

Model	Country	Program
Management services contracts, professional services contracts (curriculum design), operational contracts	Latin America and Spain	Fe y Alegría
	Colombia	Bogotá's Concession Schools
	Venezuela	Asociación Venezolana de Educación Católica
Educational services contracts for specific students	Colombia	PACES (vouchers for students from low-income families)
	Chile	Universal vouchers
Infrastructure service provision contracts	Mexico	Service Provision Projects— Universidad de San Luis Potosí
Infrastructure service provision contracts with educational services contracts	—	—

Source: Patrinos (2006).
— = Not available.

In improving educational infrastructure, it is important to anticipate the level of private sector participation in infrastructure alternatives, as shown in detail in table 16.3.

In Latin America, there are concrete examples of PPPs that are worth bearing in mind when considering new models (table 16.4). As previously noted, when PPPs are effective, they allow both sectors to work together in ways that will enable greater efficiency in the use of available resources and the timely provision of required infrastructure and services.

The Municipality strengthening for public-partnership development (MuniAPP) in Latin America

In Mexico PPPs at the federal level have been of two types: concessions and projects for the provision of services (*proyectos de prestación de servicios*, PPSs).

In an effort to promote such types of partnerships, state governments have been adjusting institutional and regulatory frameworks in order to implement local PPP projects (figure 16.4) and have been preparing to promote new plans for developing PPPs.

Municipalities lack sufficient technical and institutional resources, in turn hindering the development of PPP projects since a significant portion of municipal budgets is dedicated to current expenses rather than investments. To implement PPP programs at the state or municipal level, it is important to consider legal aspects as well as institutional and technical capabilities.

Figure 16.4. Legal Framework for public-private partnerships in Mexican states

Source: Compiled by the author on the basis of data from Woodhouse (2010).

In this context, the Instituto Tecnológico de Monterrey (ITESM) and the IDB/Multilateral Investment Fund have signed a technical cooperation agreement to implement the Municipality Strengthening for Public-Private Partnership Development (Fortalecimiento de Municipios para el Desarrollo de Proyectos de Asociación Público Privada, MuniAPP) program. This initiative aims to develop solid infrastructure and generate human capital while implementing a PPP-related permanent training and technical support service platform for municipal governments. Its overall objective is to promote the expansion and improvement of municipal services and public works through the use of PPP schemes.

The program consists of the following objectives and modules:

Module 1— Institutional platform for PPP formation (figure 16.5).
Objective: To develop a sustainable institutional platform consisting of a combination of on-site and information and communication technology (ICT) resources to provide training for municipal officials so that they can promote public infrastructure and service programs through PPP projects.

Figure 16.5. Diploma in Public-Private Partnerships in Infrastructure and Services (DAPPIS) subject areas

Module I	Models and Conceptual Aspects of PPPs
Module II	Regulatory Framework
Module III	Technical Aspects of Project Development
Module IV	Comprehensive Methodology for the Evaluation of PPP Projects
Module V	Analysis of International Models and Case Studies
Module VI	Specialized Course in Financial Modeling and Risks
Module VII	Specialized Course in Municipal PPP Projects

Source: Author.

Module 2—Institutional platform for technical assistance in developing PPP projects (figure 16.5).
Objective: To develop a sustainable institutional platform based on ICT and focused on systematically supporting municipalities in the long-term structuring of PPP projects by providing technical assistance that extends beyond the duration of each municipal administration. This platform combines personal on-site analysis and online resources that allow for the exchange of technical information pertaining to projects.

Module 3—Institutional platform for the dissemination of knowledge and lessons learned in PPPs.
Objective: To develop an institutional platform that promotes lessons learned and the knowledge garnered from the program.

The activities pertaining to this module are:

- The circulation of documents that analyze fiscal, financial, economic, legal, regulatory, and institutional models for implementing PPPs as well as a guide for best practices in municipalities
- The organization of national workshops and seminars in order to disseminate lessons learned, transfer knowledge and international best practices for PPP models, and provide training on key topics related to this type of partnership in the region
- The promotion of this field of study within the ITESM through academic research and thesis topics related to municipal PPPs
- The encouragement of city officials' participation in specialized study programs in areas related to PPPs, as well as a biannual invitation for tenders for investment projects and process innovations related to municipal PPPs
- The exploration of opportunities for cooperation with similar initiatives dedicated to developing infrastructure and services implemented by the public, private, academic, and multilateral sectors at the municipal, state, national, and international levels (IDB-TEC Cooperation Agreement, MuniAPP Program).

Diploma in public-private partnerships in infrastructure and services (DAPPIS) and technical assistance

This degree is granted by the ITESM through a series of distance-learning courses offered online via e-learning modules, and includes material and optional special activities that enrolled professionals can use to study specific topics in greater depth.

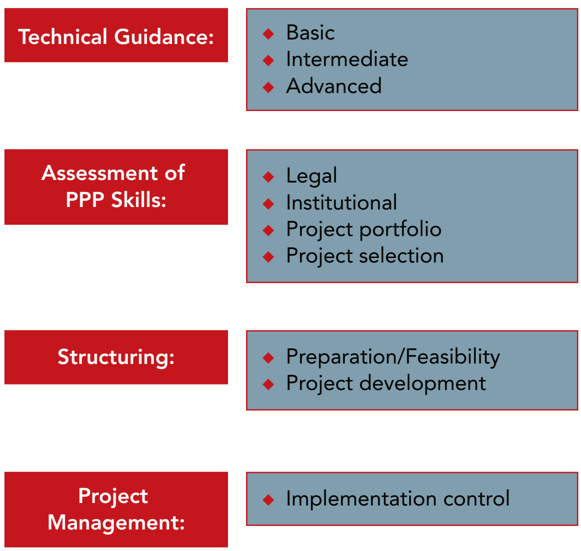
The degree program is designed for state and municipal officials, the private sector, and teachers and researchers to acquire the necessary skills to confront the challenges of incorporating the private sector into the financing and management of infrastructure and public services through various contractual PPP models.

On completion of the degree program, participants will have developed and strengthened:

- Technical skills for identifying, planning, and organizing public-private investments and for understanding the processes and procedures of structuring and implementing infrastructure and public service projects with public-private participation
- Technical skills for formulating, evaluating, and analyzing projects that allow for the optimal use of public funds
- The ability and knowledge required to interact with the various participants involved in the different stages of preparing, structuring, and delivering PPP projects.

Participating institutions will have access to a group of professionals trained in the design and implementation of infrastructure and public service projects involving private participation. Specialized legal, technical, and financial consulting services for project viability and PPP contract models will be provided by MuniAPP, as outlined in figure 16.6.

Figure 16.6. Technical assistance offered by the Strengthening Municipalities for the Development of Public-Private Partnership Projects (MuniAPP) program



Source: Author.

Public-private social partnerships

The globalization of the economy, the liberalization of markets, and an increasingly informed and demanding society are motivating change in the business world in the form of moves toward greater corporate commitment to society and regional development.

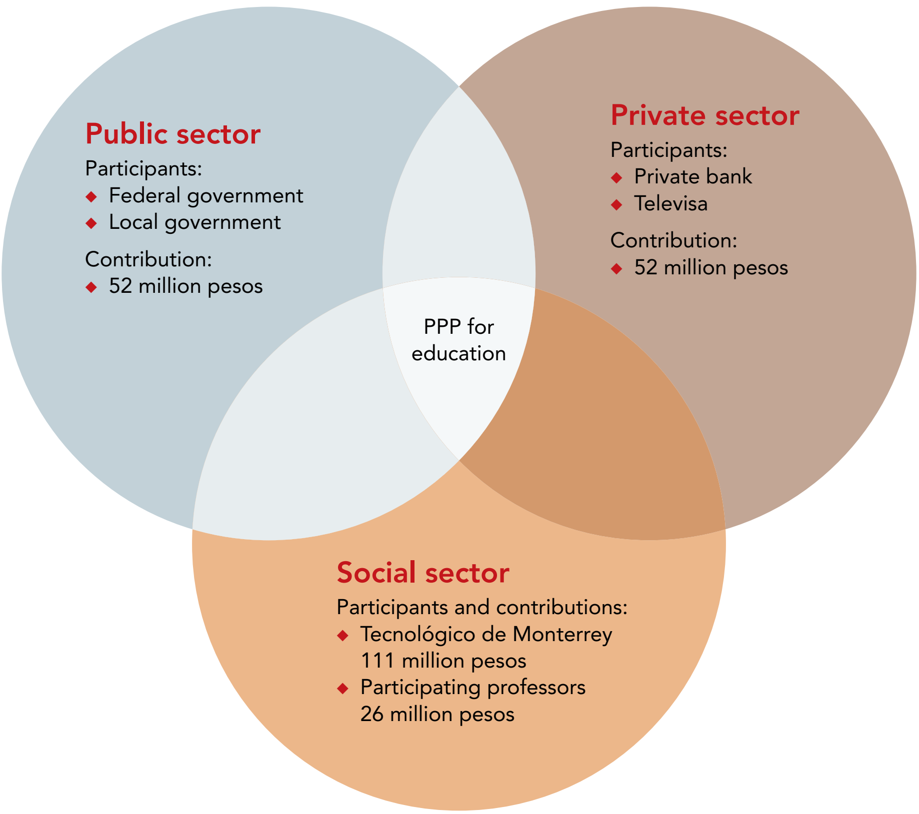
Businesses require improved social positioning and credibility and must also maintain a constructive relationship with their interest groups.

Faced with these challenges, the concept of corporate social responsibility (CSR) has emerged. CSR extends the corporate focus beyond the economic function of a corporation to matters regarding the groups involved in its corporate activities and a commitment to social issues.

This requires private initiatives to commit to economic and social development, with a vision that goes beyond philanthropy, shifts from welfarism to development, and reveals new ways of working with the public and social sectors through PPP models.

The idea is to shape a new vision that could be called "public-private social partnerships" within the framework of CSR. This concept is aligned with the World Business Council for Sustainable Development's approach to CSR, which affirms the corporate commitment to working with employees, their families, the local community, and society

Figure 16.7. Mexico's Programa Formando Formadores



Source: www.formandoformadores.org.mx.

in general to improve the quality of life. Such aims can be enriched through the creation of infrastructure and services strategically conceived as regional support.

A number of relevant examples can be found in Mexico. One is the effort to train public primary school teachers through a PPP involving the participation of the public, private, and social sectors. This initiative has invested a total of 241 million pesos over five years in the training of more than 50,000 teachers in the national public education sector through degrees that strengthen teaching and administrative skills; reading, math, and science skills; project-based curriculum development skills; and social inclusion skills. These are all key aspects of the improvement of educational quality not only in Mexico but throughout Latin America.

The investment plan can be seen by sector in figure 16.7, alongside the contributions of the participants in this extensive project.

Finally, it is worth pointing out that this PPP initiative represents the most significant scholarship program led by the private sector and ITESM. Its aim is to raise the quality of education in Mexico and to support teacher development so that students can compete in a knowledge-based society through improved performance in national and international evaluations such as ENLACE and PISA.

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17

Advantages and Disadvantages of Public-Private Partnerships

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This chapter explores the advantages and disadvantages of public-private partnerships (PPPs) and explains the role of the Multilateral Investment Fund (MIF) as a member of the Inter-American Development Group. The MIF promotes private sector development and poverty reduction by providing grants and investment to promote access to finance, markets, capacities, and basic services. The MIF can provide technical assistance grants to improve the capacity of governments to plan, implement, and monitor PPP contracts at the national and subnational levels.

Infrastructure assets and service-delivery objectives, such as school construction, are suited to the PPP model. But the right legal, regulatory, public finance, and procurement frameworks are needed for the PPP approach to work.

PPPs can be the right choice if: (i) the public sector is unable to provide adequate services through traditional means, (ii) there are certain economic characteristics that mean the service delivery is better suited to a PPP model, or (iii) the public good can be better served through the PPP approach.

Yet there are a number of potential advantages and disadvantages to developing a PPP program for infrastructure development or service delivery. Broadly, these can be grouped into the categories outlined in table 17.1.

Table 17.1. Advantages and disadvantages of the PPP model

Advantages	Disadvantages
Improved results and better performance metrics	Added costs to government and society
All-in-life-cycle costing	Political opposition
Increased private sector investment and "fiscal space"	Loss of public sector skills and danger of governance loss
Private sector innovation and better project management	Contract complexity and difficulty in renegotiation
Value for money	Long-term public sector financial commitments

Let's look at these, one by one, in order to more fully understand the purported advantages and disadvantages of pursuing the PPP approach.

The advantages of PPPs

First, PPPs may emphasize performance-based metrics rather than the traditional input-based approach. Evaluating infrastructure projects through an approach based on the actual performance of the asset means that the project's value must be demonstrated so that costs to users can be justified. Similarly, the track record of PPPs shows a higher percentage of on-time and on-budget delivery of projects, and a minimization of total costs, which means that PPPs may have better per-dollar value. In particular, the private sector may be able to introduce efficiencies unattainable by the public sector. In addition, involving the private sector may lead to superior monitoring, evaluation, and responsiveness to ensure that output specifications are met. Consequently, PPPs have exhibited a track record of increased customer satisfaction as well.

Second, PPPs may present the opportunity for all-in-life-cycle costing, or whole-life costing, meaning that complete payments are made for all elements of the project cycle: the planning, design, construction, and maintenance stages. It can be argued that in traditional procurement, payments are made for only part of the project, particularly the first three stages but not the fourth. Engaging the private sector in this fourth stage, and extending the private sector's role beyond immediate construction, can also get rid of the perverse aim of having a short-run view of construction that can lead to problems of higher maintenance costs in the long term. As a result, PPPs may encourage the costs of the investment to be spread over the lifetime of the asset, which has been shown to improve delivery time in comparison to pay-as-you-go financing. This is particularly important when taken in conjunction with the private sector's tendency to vary toll rates over the life of the asset, a step that has often proved politically infeasible in the past.

Third, PPPs may provide the opportunity for increased private investment and "off-balance-sheet" financing, since in many countries PPPs do not appear as public sector borrowing, and the initial capital cost does not appear as expenditure in the public budget. This creates "fiscal space," or room in the government's budget to provide an asset or a service to the public without harming the long-term standing of its financial position or its overall economic stability. This is because the short-term expenditure is financed through an appropriate sharing of the immediate capital investment, in the context of the longer-term revenues from the project.

Along with this incentive comes the possibility that, in addition to public funds, PPPs may allow for the public sector to gain access to new private capital, including equity and debt. It is important to note that over the long term, public expenditures on a given project may end up functioning much in the same way as borrowing would. Meanwhile, the availability of private capital allows the public sector to avoid the initially cumbersome budgetary constraints that may stall many worthwhile projects—particularly large-scale ones—before they have the chance to proceed.

Fourth, PPPs may offer the opportunity for a higher degree of innovation and efficiency owing to competitive bidding for contract rewards and the fact that private sector actors are more likely to streamline processes, seek new solutions to problems that arise, and, when necessary, accept longer hours in the face of deadlines. In real terms, private sector efficiencies may mean a lower initial investment for construction, and lower operations and maintenance costs, than under traditional procurement.

Similarly, PPPs free up public agencies to focus on their strengths, such as long-term service planning and management, issuance of permits, environmental clearance, standard setting, and other governance functions, allowing public agencies to act like the manager of a portfolio of projects while the private entity acts as the project manager that ensures the day-to-day performance of a given asset or service.

The fifth incentive is value for money, one of the more compelling and debated aspects of PPPs. For now, we simply note that value for money may improve the chances of more effective investments, which may lead to a greater return on the investment of public dollars as compared to traditional public procurement of education infrastructure.

The disadvantages of PPPs

There are also a number of disadvantages that have been reported as a result of PPP experiences across the globe.

First, PPPs may impose an added cost on society in terms of rising usage fees over the long term that exceed those typically required by a public entity maintaining a similar facility. Fees charged by PPPs will more directly depend on market conditions, thus increasing the possibility that the price paid by users may exceed the price they would pay through traditional procurement. This becomes a particular issue because the private sector is generally subject to higher costs for capital than what is available to the public sector. Moreover, these long-term costs raise concerns about fairness to the public in general and distributional impacts in particular, since fees could become a form of regressive taxation if the right countervailing measures are not put in place. For instance, increased university tuition fees (to cover more expensive PPP services) are more burdensome for lower-income users than for those to whom higher fees matter less in proportion to their income. The right policies must include ways to limit any regressive impacts from PPPs and take the common good into account.

Second, PPPs have been criticized based on the way in which they allow for "private profit at the public's expense." While the public entity may regulate the level of profits that the private sector may reap from PPPs, opposition groups have focused on this concern as one of the strongest cases against pursuing the PPP approach. When any business profits from public sector activities, it presents the opportunity for a conflict of interest and cronyism that can breed corruption. Even when corruption is kept in check, there are still cases when the private sector's revenues from PPPs exceed the value they add to the projects. In these cases, political opposition can emerge.

Third, PPPs have been criticized because they may lead to a loss of governance control in terms of the project's flexibility, adaptability, transparency, continuity of services, and preservation of other standards. In other words, a principal-agent problem emerges, as the private sector is tasked with responsibilities that it must undertake on the public's behalf. But, the public entity cannot ensure that the private agent will perform its tasks in the way that maximizes the public benefit. This is evident when we consider that the private sector's motive is profit, while the motive of the public sector is the public good. As mentioned at the outset, these concerns would become moot under the best of circumstances, considering that the governance of a PPP is ultimately determined by the government, insofar as performance metrics are contractually stipulated and effectively defined.

Fourth, PPPs require complex contracts that entail detailed analysis. To do this in the right way, PPPs may often entail additional costs to the government in the form of obtaining the services of financial, legal, and public affairs advisers who have been brought on to ensure that PPP contracts are designed and carried out in a way that best serves the public interest. This becomes particularly important with the added complexity and long-term nature of PPP deals.

Fifth, PPPs require long-term public sector commitments that are difficult to quantify, particularly in the "out years" of a contract. In some instances, PPPs may provide benefits to the private sector that would otherwise have returned to the public sector over the full life of the asset. Since unforeseen circumstances can dramatically alter the value of future revenues—both positively and negatively—it is important to keep in mind that when the public sector offers future benefits estimates to the private sector, it also may be giving up the opportunity to recover value from the asset in excess of initial estimates.

As we have seen, some of the positive aspects of PPPs that make them an improvement over traditional approaches can also lead to the risk of PPPs becoming problematic. For instance, while PPPs have been reported to improve results and increase private sector investment, they may also cost government and society more in the long run, depending on how the project is structured and managed. In many cases, the very feature of the PPP that can improve service delivery or an infrastructure asset can end up being a disadvantage that may jeopardize the project. It is important to determine, case by case, whether a PPP is the right solution for the specific context. This requires a thorough and accurate *ex ante* analysis of costs and benefits, as well as a policy framework and contract structure that allows for adaptability and flexibility.

PART 7
Green Schools

18

The Benefits of Green Schools

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What is a green school?

There is no commonly held standard for, or definition of, a green school. To add to the confusion, the terms *green, healthy, sustainable,* and *high-performance schools* are often used interchangeably.

Although there is no universally accepted definition of green schools, our survey of international green school definitions yielded some common principles—chief among them protecting the environment, lowering operating costs, improving the health and quality of the learning environment, and integrating learning opportunities within the built environment. Several sample definitions appear in box 18.1.

The lack of a commonly held definition of a green school leaves school boards in the position of defining it for themselves. Putting some real meaning behind the term can be an important first step in the development of a successful green school strategy—a chance to test assumptions and build support for setting new priorities and measures of success for school-building programs.

The next step in defining a green school is to build on the basic principles illustrated in the definitions above by asking more specific questions. What are the important expected or needed outcomes of a green school? How can developing a green

Box 18.1. Defining the green school—some examples

Council of Educational Facility Planners (CEFPI)
A healthy school cares for and looks after the overall well-being of its occupants. This school is an environment-friendly school, saves energy, and is passionate about the health of its occupants.

Collaborative for High Performance Schools (CHPS)
A high-performance green school has three distinct attributes: it is less costly to operate than a conventional school; it is designed to enhance the learning and working environment; and it conserves important resources such as energy and water.

United Kingdom's Department for Children, Schools and Families
A sustainable school prepares young people for a lifetime of sustainable living, through its teaching, fabric, and its day-to-day practices. It is guided by a commitment to care:

- For oneself (our health and well-being)
- For each other (across cultures, distances and generations)
- For the environment (both locally and globally).

Ontario Association of School Board Officials Green School's Committee
A green school is one that achieves the following:

- Supports student success
- Is financially sustainable
- Promotes environmental stewardship
- Demonstrates environmental sustainability.

school dovetail with other challenges the board is facing? What green objectives match existing board objectives? What are the green issues in the community? How would any green premium be funded—from reserves, budgets, grants, gifts? What return on investment would green features need to achieve? Which principles are flexible and which are not?

For any green school to be successful it must address issues that are relevant to the school board or community. Thus, green school principles can include issues of lowering operating costs, supporting student success, assisting in boosting attendance rates, aiding in retention of highly skilled staff, preserving limited natural resources, or building a habitat for a local endangered species. The goal is to create a definition that meets real local needs while adhering to generally accepted principles.

Why build green? The benefits of a green school

The benefits of a green school will be partly determined by the definition adopted. The following typical green school principles are used for our discussion of the benefits of green schools. Green schools should:

- Support student success
- Be financially sustainable
- Practice environmental stewardship.

Supporting student success

Student success must be the first consideration in any decision a school board makes. Green schools support student success in three principal ways: by transferring resources from infrastructure to the classroom, by building supportive learning spaces, and by engaging and inspiring students.

Transferring resources

A key principle of green design is to achieve maximum efficiency from the resources used over the life of the building. The savings from efficiency can then be reallocated to other needs. Energy, in particular, is almost always a substantial cost—and can be an equally substantial source of savings. Focusing on efficiency and low life-cycle costs can make important sums available for other uses—such as classrooms, teachers, and technology.

Supportive learning spaces

Intuitively, we understand that people who live or work in comfortable, healthy buildings are more likely to perform better. In general, scientific studies corroborate the claim that healthy buildings nurture the health of the occupants, although direct causal relationships have yet to be scientifically proven. Anecdotal evidence suggests that indoor learning environments that are dry, well ventilated, properly heated and lit with good acoustics, and free of pollutants, allergens, and pathogens will improve student comfort and performance.

An extensive review of current scientific literature carried out in 2007 by the U.S. National Research Council concluded that "a green school with the following attributes would support student and teacher health, learning, and productivity: dryness, good indoor air quality and thermal comfort, quietness, well maintained systems, and cleanliness." There is also strong scientific evidence to suggest that quality of lighting can have a significant impact on student success. The NRC study, *Green Schools: Attributes for Health and Learning*, also concluded that "A robust body of scientific evidence indicates that the health of children and adults can be affected by indoor air quality. A growing body of evidence suggests that teacher productivity and student learning may also be affected by indoor air quality."

From the available research it is clear that there are links between the built environment and student learning. What is less certain is the extent of the impact of a particular green measure. For example, studies on the impact of improved natural daylight on student test scores have shown improvements that range from the dramatic (20 percent) to the very modest (0.3 percent). This suggests a cautious approach toward green measures, even those widely thought to improve the learning environment. Improvements in the learning environment can and should be made, but investments in individual features should be made only after consulting the best currently available research.

Engaging and inspiring students

School buildings are concrete expressions of values and represent a unique opportunity to engage and inspire students. A school building that offers active energy-management and waste-reduction programs, elegant design, and creative solutions to environmental issues can become a teaching opportunity, engaging and inspiring students by showing them that something can be done about our environmental and energy problems and challenging them to do more.

Financial sustainability

Few would dispute the potential benefits of building green schools—but at what cost? In most cases, green schools do cost more to build, but with good planning, the "green premium" can usually be held to within 5 to 10 percent. A more important question is whether green schools cost more to operate. In most cases, in fact, they cost less to operate, making it possible to recoup their extra building costs quickly and generating substantial savings over the life of the building. In fact, the initial cost of greening schools is best seen as an investment that is paid back out of operational savings over the short term, which then reduces operating costs over the long term.

Schools are typically designed to last 30 to 50 years. Over that time, operational and maintenance costs will exceed by several times the entire original construction cost. Staffing, energy, water and sewage, waste disposal, cleaning, and material replacement costs are all on the rise; if not considered in the design stage, they can saddle the board with volatile costs over the life of the building.

The greatest savings will come from investments in energy- and water-efficient systems and in durable building materials. Such savings can be accurately predicted even during the building's design. Through life-cycle cost analysis, major building components, such as roofs, flooring, and cladding, can be evaluated over the life of the project, making it possible to compute future maintenance and replacement costs. Such methods allow boards to evaluate cost-saving options and to plan and budget for operating and maintenance savings before the school is even built, thus ensuring ongoing future savings that can be transferred from building operation and maintenance to other areas.

Staffing represents the largest single cost at most schools. Achieving even modest reductions in time lost to illness, fatigue, or malaise could repay investments in improved indoor environments—a win-win situation for employees and the boards. On this basis, there is a case to be made for additional investments in indoor air quality; however, research has yet to make quantifiable links between specific measures and expected health improvements. At this point, investment can be considered in relatively low-cost strategies such as low-toxicity materials, effective ventilation design, and green cleaning practices.

Promoting environmental stewardship

Current ecological thinking sees humans as a part of the ecosystem and our activities as having a positive or negative impact on nature. We depend on the health of natural systems for our well-being and, ultimately, for our survival. Problems arise when human activity (or that of any other species) unbalances a natural system to the point where it is either impaired or ceases to function.

The greatest environmental impact a green school can have is its influence on students and the school community. By displaying tangible lessons of environmental stewardship, the green school demonstrates that "something can be done." Green schools inform students about stewardship practices that can be implemented today and can inspire a generation of future environmental leaders.

Ontario's Green Schools Pilot Initiative has the potential to make social change on a broad scale. One in five Ontarians learn or work in an Ontario school every day. By linking school buildings to an environmental education curriculum, demonstrating to the school community how much can be achieved by green building, and instilling positive environmental habits in students and other building users, the initiative is reaching a very large group of people. Schools that have implemented student education programs have seen energy savings of more than 10 percent and waste reduction of more than 15 percent. The positive behavior that brings about such results is likely to extend beyond the school building and into the broad community.

Green school buildings can also lead to market transformation. The building of K–12 schools is a large construction sector. Such a large volume of expenditure in a single sector provides leverage and an opportunity to set an example for the entire construction industry.

Green schools also serve as showplaces within the community where efficient, economical, and effective new technologies, materials, and products can be demonstrated. Well-planned green school buildings will expand the market for green roofing, solar power, energy- and water-conserving fixtures, and innovative construction technologies.

How to build green: Nine keys to a successful green school strategy

Success in building green schools stems not from a magic technical bullet or green feature, but rather from a comprehensive strategy based on careful planning, one where goals are clear and realistic and stakeholder consensus is built around shared benefits. Even large-scale investment is ineffective if not backed up by strategic planning and stakeholder buy-in. School boards have used several key approaches to increase the likelihood of successful implementation of a green school program.

Establish clear green objectives and build support early on

Set clear green objectives early with input from key stakeholders. These objectives will be used as a touchstone during the design, construction, and evaluation of a project. Clear objectives help ensure that all stakeholders are on board early on, limiting the need for costly corrective actions later in the project's design or construction and reducing the likelihood of surprises on opening day.

Because greener schools will require some degree of change—in how construction is funded, how systems are designed, or how a building is maintained—support from stakeholders must be secured early on in the process. External supporters may also bring additional funding, experience, or assistance with approvals.

Integrate green approaches into ongoing initiatives and go green gradually

Most successful green designs build on initiatives that boards are already undertaking and make use of skills currently available to the board. Too often, "bolt–on" environmental features that are too exotic or not seen as relevant are not maintained after the initial enthusiasm fades. The green approaches selected should answer real challenges that the board is facing in an effective and achievable way.

Most boards do not build new schools on a regular basis and, to make their new building as green as possible, may be tempted to implement a wide array of green features as soon as they get the chance. But it is important to temper experimentation with more conventional approaches. Greening in small steps, possibly through retrofits of existing schools, gives the board a chance to become familiar with and test new green approaches. Nothing can turn the tide against a green school program faster than implementing a system that fails; a failed approach can leave a strong "been there, tried that" attitude that entrenches a "stay the course" attitude and may cause the board to overlook truly beneficial green approaches or improved technologies.

Set a whole-life building budget and optimize investment

A board that saves on construction costs only to be saddled with higher long-term operation and maintenance costs has not realized any savings at all. Thus, capital costs must not be considered in isolation from operation and maintenance costs. Budgets should consider costs over the entire life of the building and may be presented in the context of a construction budget with a payback period for any premium over the base budget. Budgeting may also include extramonetary items, such as carbon emissions reduction and water conservation.

Both in financial and environmental terms, proposed measures should be evaluated for their return on investment. Are the proposed measures the right ones for this school, the environment, and the pocketbook? A key tool to optimizing green investment is the Integrated Design Process, in which all stakeholders are brought together to identify win-win solutions that can reduce costs while improving environmental performance. Another key to optimizing investment is to start with energy saving. Energy economization provides predictable savings in operation costs and short payback periods on initial investments. Most schools could achieve 25 to 35 percent energy savings by investing as little as 5 percent more than conventional construction costs. A sample energy savings scheme is presented in table 18.1.

Assemble the right team

The right team includes school board staff from all departments and at all levels of authority to ensure a clear, shared vision is shared by all, from strategists to the front line. The board should also evaluate their in-house expertise and hire consultants that bring the needed experience and skills. Specialized green consultants, energy modelers, and commissioning agents should also be considered.

Own the green school and commit to continuous improvement

Successful green processes require substantial overlap between planning, design, construction, and occupancy. Thus, the behavior of operators and occupants can have just as great an impact as design, equipment, or materials on green outcomes. The Canadian Green Building Council has found that design, operation, and behavior each share a

Table 18.1. Sources of savings on energy costs

Strategies	Fraction of energy savings (%)	Savings on yearly energy costs (%)	Capital cost ($/sq.ft.)	Yearly energy savings (MJ/sq.ft.)	Yearly cost savings ($/sq.ft.)	Net present value ($/sq.ft.)
Envelope						
High-performance building	14	5	0.20	6.47	0.08	0.55
Heating/cooling						
High-efficiency boilers	25	9	1.00	11.65	0.14	1.33
High-efficiency DHW heaters	14	5	0.20	6.47	0.08	1.09
VSDs on pumps, high-efficiency fans	8	3	0.25	3.88	0.11	1.53
Ventilation						
Ventilation heat recovery	25	9	1.00	11.65	0.14	1.33
Lighting						
Efficient lighting design	13	4.5	0.10	5.82	0.16	2.57
Total	100	36	2.75	45.95	0.71	8.40

Source: Author's energy model for a typical Ontario school. Figures will vary with climatic conditions, construction norms, and construction and energy costs.

one-third responsibility for long-term energy performance. Green schools demand that building operators and users become more aware of their role in supporting the green design and building objectives. This means users must be informed and active occupants, and operators must understand the green intent behind the design.

A green school is not a static concept. Just as energy efficiency has improved over time, so will the environmental performance of green schools. Feedback loops must be developed to influence the design of tomorrow's schools based on the real-life experience of operating current schools.

Annex 1

Conference Agenda

Regional Policy Dialogue on Infrastructure and Learning in the XXIst Century

Santiago, Chile, October 26–27, 2010

Hotel Inter-Continental, Santiago, Chile

The purpose of the "Education Network Regional Dialogue" is to identify and engage players in the region to foster collaboration and share key information about school designs better adapted to a modern curricula; create awareness in the region about the existing gap in infrastructure and show alternative finance models used in other countries to improve accessibility. The expected result is a quality of education in the region that focuses on the design of and access to infrastructure as an important factor conducive to a better teaching and learning performance.

Tuesday, October 26

8:00–8:30	**Registration**
8:30–9:00	**Introduction** *Jaime Sujoy, IDB Representative in Chile* *Fernando Rojas, Under Secretary of Education in Chile* *Marcelo Cabrol, Chief of Education Division, IDB*
9:00–10:00	**SESSION I. Pre-School Designs** *Speakers:* *Peter C. Lippman, Architect, AIA, REFP, EIW Architects, Australia* *R. Thomas Hille, Architect, AIA, USA* *Moderator: Victor Serrano, Architect, Fundación INTEGRA, Chile*

10:00–10:15	**Coffee Break**
10:15–11:15	**SESSION II. Elementary School Designs** *Speakers:* *Sean O'Donnell, Architect, Ehrenkrantz Eckstut & Kuhn Architects, AIA, LEED AP, Principal, USA* *Ricardo Santocono, Architect, Ministry of Planning, Argentina* *Moderator: Javier Duhart Smithson, Ministry of Education, Chile*
11:15–11:30	**Coffee Break**
11:30–12:30	**SESSION III. Middle School Designs** *Speakers:* *Jadille Baza, Architecture Chief, Infrastructure Unit, Ministry of Education, Chile* *Lucas Fornari, Architect, Studio Altieri, Italia* *Moderator: Carlos Fernando Gonzalez Mena, Director of Building and Conservation in Education Establishments, Department of Education in Bogota, Colombia*
12:30–14:00	**Lunch**
14:00–15:00	**SESSION IV. Reconstruction and Prevention against Hurricanes and Earthquakes** *Speakers:* *Alejandro Boetsch, Chief of Emergency Team, Ministry of Education, Chile* *Rima Taher, Ph.D. PE, New Jersey Institute of Technology—College of Architecture & Design* *Jaime de La Garza Reyna, Architect, Consultant for CISEM in Italy, Mexico* *Moderator: Juan Pedro Egaña, Director of the Infrastructure Department, Ministry of Education, Chile*
15:00–15:15	**Coffee Break**

15:15–16:15	**SESSION V. Impact of School Infrastructure on Learning** *Speakers:* *Carol S. Cash, Clinical Assistant Professor, School of Education/ELPS, Virginia Tech, USA* *Carlos Gargiulo, Lead Education Specialist, Education Division, IDB* *Moderator: Marcelo Cabrol, Chief of Education Division, IDB*
16:15–16:30	**Coffee Break**
16:30–17:30	**SESSION VI. Discussion Panel—Education and Infrastructure** *Moderator: Juan Pedro Egaña, Director of the Infrastructure Department, Ministry of Education, Chile*
19:30–	**Cocktails—Hotel Intercontinental, Santiago**

Wednesday, October 27

9:00–10:00	**SESSION VII. Management and Financing in Infrastructure Public-Private-Partnership (PPP)** **Spanish and Chilean Concessional Models for Infrastructure in Social and Public Facilities** *Speaker: Antonio M. Lopez Corral, Professor, Universidad Politécnica de Madrid, Spain* *Miguel Angel Jara, Chief of Projects, Coordinación de Concesiones, Chile* *Moderator: Cristina Holuigue, Academic Master of Public Policy, Faculty of Economics, Universidad de Chile*
10:00–10:15	**Coffee Break**
10:15–10:45	**Private Finance Initiative Model (PFI) for the United Kingdom and Building Schools for the Future Model (BSF) and its Adaptations to Latin America** *Speaker: Germán Millán, Director for LA in Chile, Turner and Townsend, Chile*
10:45–11:15	**Discussion Panel—Private Sector and School Infrastructure** *Moderator: Sergio Hinojosa, Program for the Implementation of APP in Mexico*
11:15–11:30	**Coffee Break**

11:30–12:30	**Role of Non-Governmental Organizations in Management and Financing in the Education Sector and Support for Municipalities in PPP** *Speakers:* *María Adelaida López, Pedagogic Director, Fundación Carulla—aeioTu, Colombia* *Laura Ruiz Perez, Director of Social Programs, Tecnológico de Monterrey, Mexico* *Moderator: Carlos Rubilar Camurri, Chief Advisor of JUNJI, Chile*
12:30–14:00	**Lunch**
14:00–14:30	**Advantages and Disadvantages of PPP Model Approaches** *Speaker: David Richard Bloomgarden, Lead Private Sector Development Officer and Coordinator, Multilateral Investment Fund*
14:30–15:45	**SESSION VIII. Green Schools** *Speakers:* *Peter Duckworth, ZAS Architects and Interiors, B.E.S., B. Arch., LEED AP, Principal, Canada* *Aldo Cerda, Forest Area and Eco-Business Manager, Fundación Chile Área de Sustentabilidad, Chile* *Moderator: Christoph Tagwerker, Energy Efficiency Consultant, INE/ECC, IDB*
15:45–16:00	**Coffee Break**
16:00–17:00	**SESSION IX. Discussion Panel—Infrastructure and Schools in the XXIst Century** *Moderator: Marcelo Cabrol, Chief of Education Division, IDB*
17:00–17:30	**Wrap-Up Session** **Next Steps and Closing Remarks:** *Carlos Gargiulo, Lead Education Specialist, IDB* **Final Remarks:** *Jaime Sujoy, IDB Representative in Chile* *Marcelo Cabrol, Chief of Education Division, IDB*

Education

Learning in Twenty-First Century Schools

Toward School Buildings That Promote Learning, Ensure Safety, and Protect the Environment

In 2006, the Education Division of the Inter-American Development Bank (IDB) created the Education Network under the framework of the IDB Regional Policy Dialogue in order to improve education policies and programs in Latin America and the Caribbean (LAC). Network participants tackle common problems, identifying opportunities for technical cooperation between countries in the region. They endeavor to raise political awareness about the importance of education, increase the efficiency of the sector, promote greater equality in the quality of and access to education, and achieve a safer educational space for students and teachers—one better adapted to the task of providing a modern and high-quality education.

Since the 1990s multiple studies have stressed the close link between infrastructure and learning. In 2010 the Education Network organized an event that examined the state of school infrastructure in the region and the financial role of the private sector. Infrastructure and Learning in the 21st Century was held in Santiago, Chile, on October 26–27, 2010.

This book contains the presentations made at the conference, edited and, in some cases, revised for publication. The chapters of the book follow the conference agenda, which focused on designing, financing, building, and maintaining school buildings.

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