INTEGRATION PATTERNS OF LEARNING TECHNOLOGIES

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Dissertation submitted to the faculty of

Virginia Polytechnic Institute and State University

In partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Architecture Design and Research

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September 10, 2007

Blacksburg, VA, USA

Keywords: building systems' integration, learning environments, pattern language

IRB# 05-295-06

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ABSTRACT

This research proposes sets of design patterns of learning environments as an innovative approach towards an intelligent architectural design process. These patterns are based on teachers' spatial and pedagogical use of their learning environments.

The study is based in the desired condition that learning environments are expected to host learning technologies efficiently, to adapt to the fact that its life span is much longer than that of any technology within it, and to accommodate a variation of teaching modes and learning styles. In an effort to address these issues; calls for designing flexible learning spaces have emerged, as well as recommendations for alternative layouts. Yet, more challenging questions emerge; how efficiently do these technologies integrate with other systems in the classroom space? What should architects and facility planners consider for a successful systems' integration which incorporates learning technologies in the design of the classroom space? And how can these spaces support variations in pedagogical practice. This study attempts to answer these questions by developing a pattern language to support the early design phases of a technology-rich learning environment.

The study is qualitative in nature, and based on interviews with a sample of teachers at academic year Governor's science and technology schools in Virginia. The researcher attempts to capture problems and challenges related to occupants' performance within the physical boundaries of the classroom when learning technologies are in use. The variation of teaching-learning modes is taken into consideration.

In this process, the researcher focuses on integration patterns of learning technologies with the envelope and the interior systems. The findings are then translated into the design language in the form of a pattern language at the building systems scale.

DEDICATIONS

This work is dedicated to all my family, big and small, those who left us, those who are with us today and those whom we haven't met yet.

From the heart to my father and mother for everything I am now.

To my husband for his support, patience, tolerance, and certainly for his kind heart.

To my kids for everything they were deprived from in the duration of this work.

Without all of you I wouldn't have been here today.

ACKNOWLEGMENTS

Sincere thanks to Dr. Jim Jones, my advisor for all of the valuable learning opportunities which he offered along the way. His thoughtfulness, patience and guidance have continually supported me both academically and personally. I also like to thank him for being a brother to me away from home in many difficult and incomprehensible times.

Special thanks to my committee members; Dr. Glen Earthman, Dr. Dan Dunlap, Mr. Robert Schubert, and Mr. Dennis Jones for all their contributions during my experience as a doctoral student. Their help, encouragement and support meant a lot towards establishing this goal. They have been significantly resourceful and inspiring in many ways. I am so grateful for knowing each one of them both as a teacher and as a person.

Cordial thanks to the ladies of my support group MadCAUS; Marilyn Whitney, Elizabeth Grant, Tao Huang, Kristin Maki, Nancy Becerra-Cordoba, Ceylan Oner Asli for all emotional and academic support they offered, and mostly for being there for each other, and for sharing many precious moments together.

Thanks to everyone who taught me a valuable something in Virginia Tech. Special thanks to Dr. Dennis Kilper, Dr. Max Stephenson, Dr. Shelli Fowler, and Dr. Penny Burge.

My gratitude to my parents, my family and my friends from Egypt goes beyond description. Thanks for their continuous support, concern and prayers during this journey. Also, all my friends whom I met in Blacksburg who offered their kind support in every occasion, happy and sad; thanks for being there for me and my family.

Last, but never the least, I would also like to thank my professors and colleagues in Alexandria University, Egypt for facilitating this opportunity and for their continuous support and thoughtfulness.

You are all an important part of this success.

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CHAPTER 1 **INTRODUCTION**

Students today expect to utilize progressive technologies in their learning experiences; teachers are also becoming increasingly aware of the important role these technologies play in supporting their work. Accordingly, the classroom space is expected to host these technologies efficiently, to adapt to the fact that the life span of the classroom is typically longer than that of any technology within it, and to accommodate a variety of teaching modes and learning styles. In an effort to address these issues; calls for designing flexible learning environments have emerged, as well as recommendations for alternative space layouts.

Generally, learning environments are spaces with a rich potential for systems' integration, which is proven to be a major component of building intelligence. In order to be able to respond to current pedagogical practices, these systems should be integrated in a manner flexible enough to accommodate different occupancy and activity patterns in the classroom, to adapt to variable teaching/learning dynamics, and encourage individual teaching instances as efficiently as team teaching.

The study is qualitative in nature, and is based on interviews with a sample of teachers from Academic Year Governor's schools and Science-and-Technology schools in Virginia. It addresses these emerging issues and focuses on integration patterns of learning technologies with the envelope and the interior systems as they pertain to occupants' performance. The findings are then translated into the design language in the form of a pattern language at the building systems scale to support the early design phases of a technology-rich learning environment. The variation of teaching-learning modes is taken into consideration.

The broad goal of this study is the development and utilization of knowledge-support structures that can be used by architects and building engineers to make more informed, intelligent decisions concerning building design. A form of artificial intelligence, the goal is establishing the possibility of linking these decision-support structures to computing environments; a goal which is foundational, yet beyond the objectives of this particular study. The methods described in this study represent knowledge collection and structuring that once completed, can be adapted to an intelligent computing environment. Through the implementation of these knowledge-based decision-support structures the depth of analysis for any particular design option can be extended, thus this approach "extends" the designer's knowledge in an artificial sense.

Specifically, the study adopts programmatic building systems' integration as a process highly considered by architects and facility planners for achieving the desired balance in building performance as a step towards building intelligence. It is argued that by adopting this approach, designers and decision makers will gain an awareness of the interrelated nature of the choices or decisions involved; be able to recognize and choose patterns or change them; and to reduce the amount of time, material, and space employed in a building while increasing the number of activities that can take place within it (Rush, 1986, p. 317).

This kind of control lends the decision-maker an ability to meet higher performance standards. Rush (1986) classifies performance mandates within a space into spatial, thermal, visual, acoustical, air quality and building integrity. Despite the fact that aesthetic qualities, architectural expression and economic performance are less considered in the integration equation; they are not less important for a successful building.

Arriving at an integrated scheme requires attention to systems' components, their functions and the ability to synthesize the requirements of each into an overall plan (Bachman, 2003; Rush, 1989; Wigginton and Harris, 2002). This plan should address users' needs which are considered the primary deriver of design in a performance-based approach. In this approach, the building attributes are described and specified, and only then many combinations of different building parts can be procured as illustrated in Figure 1-1 (Foliente, Leicester and Pham, 1998, p.19). As opposed to that, in the typical prescriptive approach the building parts are described, specified and procured, resulting in a building with a unique but implicit set of attributes.

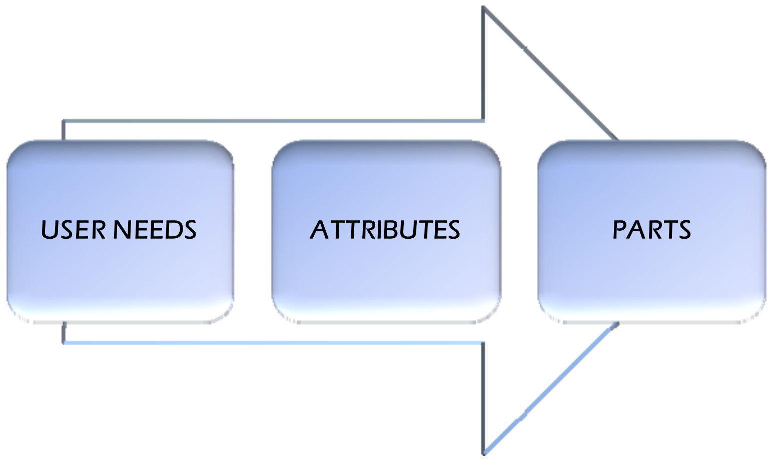


Figure 1-1 Design progress in a performance-based approach

Foliente, Leicester and Pham (1998, p.19) argue that "since human requirements are the defining parameters for the building attributes, their proper definition and articulation are required in the development of performance criteria. This process requires research on human requirements, and human response to the built environment." This approach is implemented through this study by interviewing teachers at their learning environments, seeking an understanding of their performance when it comes to designing an integrated learning environment.

1.1 Limitations of Existing Methods and Tools

"Among the many methods employed to foster student development, the use of the physical environment is perhaps the least understood and the most neglected." (Banning and Canard, 1986)

Teaching and learning activities still take place in spaces unable to accommodate different pedagogical models, and not designed to integrate rapidly-developing learning technologies with other physical systems in the space. This situation does not enhance the teaching-learning experience, which calls for higher response to users' needs in the design of contemporary learning environments.

At the same time, current architectural practices do not expand the idea of high performance, which has been adopted for decades, to include high occupants' performance, which is a critical issue when it comes to designing a contemporary learning environment hosting a variety of pedagogical practices.

Learning technologies are also becoming a major component in the classroom space. Yet, including learning technologies in a programmatic integration scheme is not consciously considered in an intelligent design process. There is not a specific tool available to support designers' decisions for implementing this integration scheme. It is a goal of this study to fill this particular gap by developing a pattern language to support early design decisions in the design of learning environments at the building systems scale.

Previous research efforts in this field have not proposed patterns at the building systems' scale. Pattern languages currently developed for educational facilities are limited to planning and spatial organization (Lackney, 1999; Moore & Lackney, 1994; Moore & Lackney, 1995; Nair, 2004; Scott-Webber, 2004).

1.2 Objective Statement

The broad goal of this study is the development and utilization of knowledge-support structures that can be used by architects and building engineers to make more informed, intelligent decisions concerning building design; a form of artificial intelligence. The methods described in this study represent knowledge collection and structuring that once completed, can be adapted to an intelligent computing environment. Through the implementation of these knowledge-based decision-support structures the depth of analysis for any particular design option can be extended, thus this approach "extends" the designer's knowledge in an artificial sense.

This study aims at developing a pattern language for integrating learning technologies with the interior and envelope systems of learning environments. The proposed patterns are developed at the building systems scale and respond to occupants' performance when learning technologies are in use.

For the purposes of the study, the interior system of a learning environment in its most basic form consists of a physical space that supports the prescribed teaching-learning activities and consists of the circulation component, lighting system, furniture, equipment, and heating and ventilation (HVAC) systems. While its envelope system is defined as the architectural element(s) which provide protection for the enclosure, as well as balanced penetrations of internal and external environmental forces and consists of the walls, floor, ceiling and openings within the envelope (Bachman, 2003; Rush, 1986).

The proposed pattern language, despite being primarily architectural, is designed to communicate with most decision-makers participating in the design process of learning environments. For that, the language avoids complexities, reflects teachers' needs as they pertain to their pedagogical approaches and considers the fact that architects are not the sole decision makers in the process.

The following particular research objectives and tasks are addressed throughout the study:

1. Defining contemporary learning environments and their components.
2. Identifying variations in pedagogical practices and learning technologies hosted in contemporary learning environments.
3. Defining performance mandates which dictate the potential for architectural systems' integration within learning environments, and testing for integration levels possible with learning technologies.
4. Developing design pattern language for integrating learning technologies with the interior and envelope systems in the space as responds to pedagogical practices in learning environments.
5. Identifying potential integration levels of these technologies with the components of the envelope and interior systems.

1.3 Scope of Research

This research proposes a holistic view for designing technology-rich learning environments. A review of related literature shows that integration patterns are products of well-studied integration variables and different performance goals of the space. Figure 1-2 presents the major areas of study upon which this research is based, while figure 1-3Figure *1-1* illustrates the main considerations within these areas of study. The highlighted boxes are the focal points. Among the many components of the overall map, this research focuses on the integration of learning environments with the envelope and interior systems in the architectural space.

1.4 Research Limitations

This study has the following limitations:

- **Systems:** Due to the wide scope of the selected topic, this study only investigate patterns of integrating learning technologies with two systems in the architectural space; the envelope and the interior.
- **Design Patterns:** the patterns proposed in this study are focused on the building systems scale, and is primarily concerned with integrating learning technologies with the components of the envelope and interior systems.
- **Research Sample:** the research sample is limited to twenty five classrooms at Governor's Schools and science and technology schools in Virginia. The selected sample falls within 300 miles from the Virginia Tech campus.

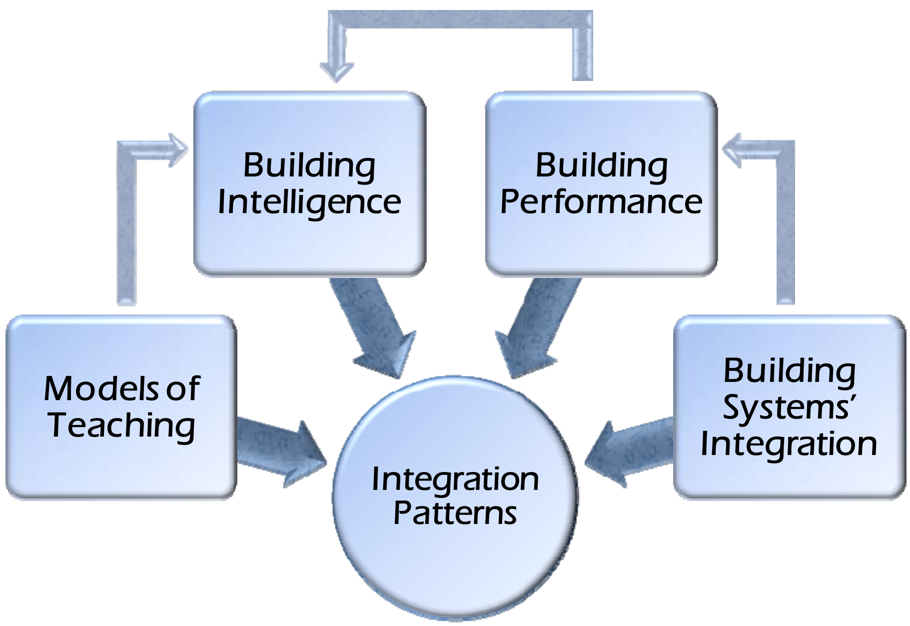


Figure 1-2 Major areas of study

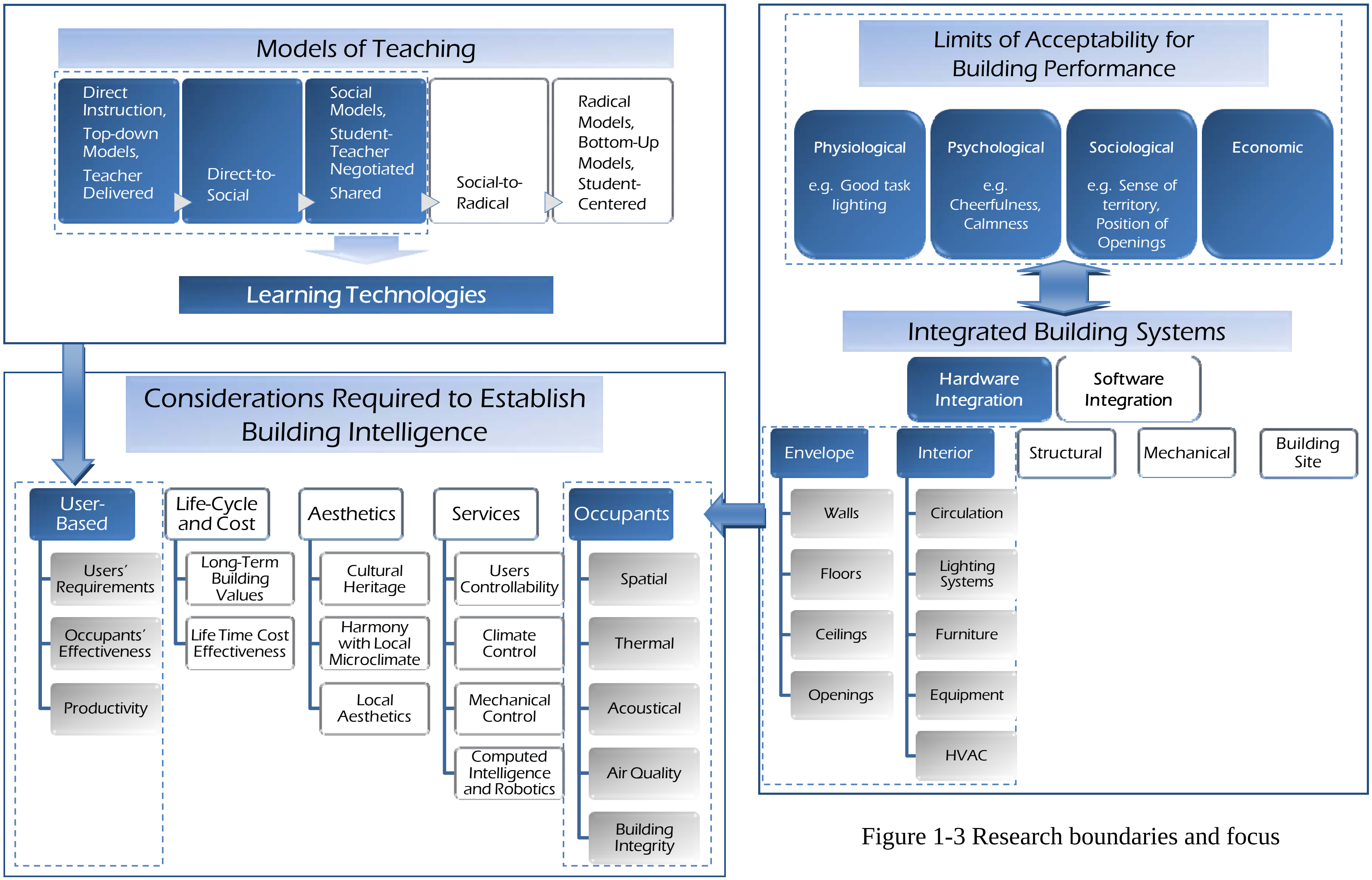


Figure 1-3 Research boundaries and focus

1.5 Organization of Dissertation

The dissertation is presented in six chapters. This chapter, Chapter One (Introduction), lays out background information, reviews the concept of systems' integration, and addresses research questions and objectives. It also discusses the scope and limitations.

Chapter Two (Intelligent Design and Integrated Building Systems) reviews the basic concepts of intelligent design problems. It also presents the pertinent research on integrated building systems, and discusses its position in the intelligent design process. It also discusses pattern language and its applications in designing learning environments.

Chapter Three (Contemporary Pedagogy and the Design of Learning Environments) reviews contemporary pedagogical approaches and their influence on the design of today's learning environments. It also defines the term 'Learning Environment' and outlines the major pedagogical factors that should be considered in its architectural design.

Chapter Four (Research Design) reviews methods adopted for the study, the selected research sample, data organization and reduction as well as the research process.

Chapter Five (Emerging Themes and Patterns) Presents the research findings in the form of design patterns at the building systems scale, as well as the potential integration levels between learning technologies and the components of the envelope and interior systems. It also discusses assessment for research quality through a number of verification procedures.

Chapter Six (Conclusion and Interpretive Readings) presents general concepts and guidelines, contributions of the study. It offers interpretive readings of the research process and findings. It also suggests future research that may extend the concept.

CHAPTER 2 INTELLIGENT DESIGN AND INTEGRATED BUILDING SYSTEMS

The goal of this chapter is to gain an understanding of how the proposed pattern language is able to communicate integrated-design solutions for learning environments in an intelligent-design scheme. How these issues and tools are related and how they prove the process to be "intelligent" in nature through the basic definitions of integration.

This chapter generally reviews models of human behavior in problem-solving contexts, and similar models pertinent to problem solving in design. It then defines and discusses the basic concepts of intelligent design and the pertinent research on integrated building systems. It also discusses the position of integration in the intelligent design process. It finally defines and discusses design patterns as means of communicating design situations visually.

2.1 Human Behavior in Design and Problem-Solving Context

Design as a discipline of human inquiry belongs to the category of behavior called teleological or goal seeking behavior. More specifically, design is "a thinking behavior which conceptually selects among a set of alternatives in order to figure out which alternative leads to the desired goal or set of goals" (Churchman, 1971, p. 5). Ideally, each alternative describes a complete set of behavior patterns, so that someone equipped with the same thought processes as the designer will be able to convert the design into a specific set of actions.

Thought processes are illustrated through research in the form of problem solving models which represent how the human mind reacts to solve a specific problem. Problem solving in architecture is no exception to these models.

One of the earliest models of human problem solving as presented by Wallace (1926) is derived from introspective accounts and consisted of four stages (Blum, 1996, p. 113); (a) preparation, in which the problem is investigated in all directions; (b) incubation, during which there is no conscious thinking of the problem; (c) illumination, which is characterized by the appearance of the "happy idea;" and (d) verification, during which the idea is verified using knowledge of the initial problem. This model relegated problem solving to the unconscious.

In contrast, the information processing models of the 1970s and beyond recognize the contents of the memory which operate by pattern matching (Blum, 1996). Negroponte (1975, pp. 64-65) presents such a model by classifying the process into three stages; (a) recognition, where inputs are employed to make judgments and to build evidence about what is “true” and what is “false;” (b) data collection and sorting, which may be then weighted and mapped upon an existing (and ever growing) table of entries, response, and learning; and finally, (c) response, where different aspects resulting from recognition are categorized within three domains of response; the environmental, the operational, and the informational. The final stage will then be Learning, or modeling the inhabitants.

As mentioned earlier, problem solving in architecture is no exception. Generally, any statement of an architectural problem is a mixture of a set of criteria or targets and a set of constraints or limits, and as long as the constraints do not contradict themselves, the problem is solvable. Meanwhile, if only criteria are specified, there exist an infinite number of possible solutions (Negroponte, 1975).

In a systems-based approach, one can recognize two basic methods for architectural problem solving; one produces the requirements for a buildable system by closing the open constraints, this can be established by weighing criteria in relation to each other in order to create a common unit for comparison in testing (Negroponte, 1975; Reitman, 1965). Another method restructures the problem to reuse existing solutions, perhaps by rephrasing the problem statement making one of the criteria into a constraint. Normally, any project employs both methods (Blum, 1996, pp. 132-133).

The performance-based approach adopted throughout this study and as explained in chapter one is a practice of the later approach; where the building attributes are described and specified based on human requirements. Only then, many combinations of different building parts can be procured (Foliente, Leicester and Pham, 1998, p.19). Generally, this process requires research on human requirements and human response to the built environment as adopted in the methodology of this study.

A number of design models have emerged for architectural problem solving through research. Linear design models are the most logical, straight-forward models although they do not simulate human reasoning or real life practice. Mitchell's model (Mitchell, 1990, pp.53-57) as illustrated in Figure 2-1 is an example of a linear design model; the design universe is pictured as a state-action tree in which the root is the initial state, internal nodes are possible states, and the branches are available design operations. The sequence of nodes along this path describes the evolution of the designer's knowledge about the form of a design proposal. The tree may not always be traversed in a forward direction: sometimes a designer decides that a line of exploration is not fruitful and so retracts some design moves to return to a former node, perhaps even to the root of the tree.

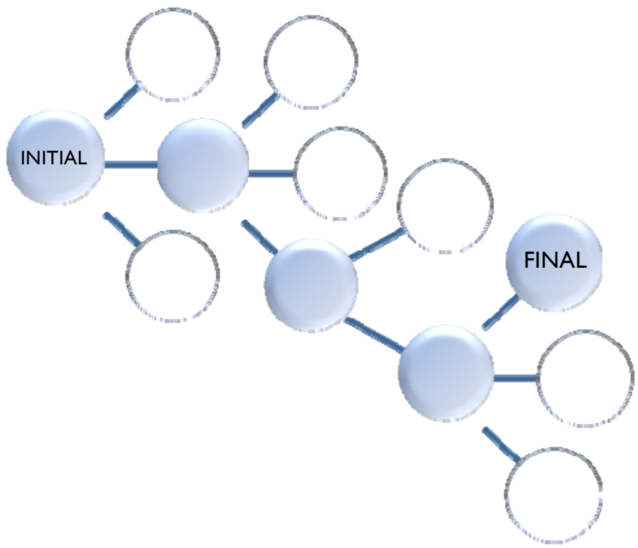


Figure 2-1 Part of the state-action tree for a design world

Another model introduced by Sam Miller (Miller, 1995) better illustrates design in the real world and is the most descriptive of the actual performance of human problem solving. According to this model as illustrated in Figure 2-2, the design process (cycle of learning) over which each individual designer spins his/her own particular style. It investigates a fundamental cycle of information gathering by the designer, this cycle is followed by creative synthesis on a continuing basis, then a return to the facts for checking, communication, and feedback.

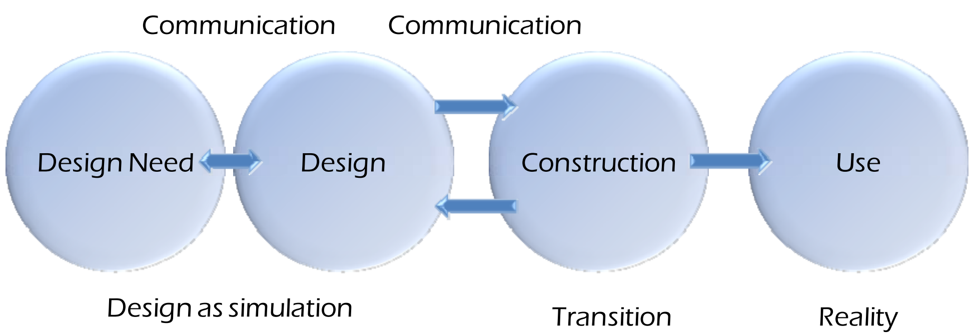


Figure 2-2 Real-world design model

When processing according to one of the approaches described above, the designer muddles his way through during the process, and then he is able to evaluate the outcomes of the project after completion so that we can be informed about the next design effort.

Other models emphasize the importance of providing more opportunity for "episodic" research within the larger domain of design. These approaches can combine design and research in various levels depending upon the design situation; some hold the concept that theoretical knowledge and practical knowledge must inform each other in a concrete context for the establishment for a true domain or field of endeavor (design as action research). While other models, like the generator or the conjecture model, tries to defy the "black box" concept by learning how to design by a more explicit awareness of the attributes that characterize design in general (Groat and Wang, 2002, pp.108-118).

In today's world, design projects are increasingly complex and involve different expertise and disciplines along with architects and architecture. This model calls for "interdisciplinary" design research to shift from the model with the architect as the sole technician, artist or decision-maker in the project.

This study merges both design as action research and design in collaboration approaches; as it studies the design of learning environments in a real-life situation. Meanwhile, it represents a design methodology which involves other stake-holders in the design process of learning environments.

2.2 Satisficing Design Decisions

When approaching an intelligent design process to integrate learning technologies in the classroom space, there is no one-best solution to any of the design problems addressing occupants' performance. This is because architectural decisions generally fall under the category of "wicked problems," as defined by Blum (1996); they are problems that cannot be solved; they can only be resolved, and their solutions are not true-or-false but rather good-or-bad. In solution to wicked problems, Blum suggests utilizing an approach he calls "adaptive design in context;" this paradigm is problem-oriented, and there always will be a fuzzy boundary about what we can and cannot do (p. 272).

Also, Byron (2004) argues that humans are not equipped to maximize (one way to optimize) in the first place, thus we often choose "the next best alternative," one that is no more than satisfactory; this strategy is known as satisficing; a term first coined by economist Herbert Simon (p. 1).

Satisficing is, by nature, an adaptive-design-in-context approach; it calls for looking for "good solutions," which are not necessarily the best, but ones which sound more appropriate to architectural solutions, because they enable the decision maker to consider and display a variety of solutions, "each of which may stem from a very different interpretation of 'good,' and most important these variations in 'goodness' do not come from variations in parameter weighing, but from context".

Therefore the purpose of satisficing is to include contextual variants, especially in cases where the outcomes of courses of actions are not predictable, and results could not be weighed, which is the default case for almost all architectural problems (Negroponte, 1975; Schmidtz, 2004). This approach is highly considered throughout this study, since variations of individual pedagogical approaches of each participant is considered a primary deriver of the design process.

2.3 The Intelligent Building and Intelligent Design Process

This section explains the role of the design component in labeling a building as "Intelligent", and the position taken in this study that the process adopted falls under the category of the Intelligent Design Process.

The term Intelligent Building (IB) came into use several decades ago, probably as a mere commercial slogan. It insinuated high quality and possible fast return of the invested money. At the same time the actual, quantitative definition of the building's merits was vague and the meaning of building intelligence was subjected to personal interpretation of both the entrepreneur/owner and the user/buyer (Arkin and Paciuk, 1997).

The interpretation of building intelligence varied in geographic regions; in the United States the most important feature of an IB was the inter-connection of service systems for the benefit of occupants, while the Europeans emphasis for the IBs lay in the interaction between the systems and the responsive structural elements. In Japan, the significance of intelligence was directed to the use of new, advanced technologies for data and information transfer in order to improve the building's capability in organizational, supervisory aspects (Arkin and Paciuk, 1997, p.471).

Koner (1997) introduced more aesthetic aspects to the definition of an intelligent building; he suggested that its form embodies an attitude which is experienced by living in and with its spaces and places (p.381). An intelligent building, accordingly, should incorporate indigenous building materials and the work of local craftspeople; and benefit from the intelligence of occupants in conjunction with the facility management team for its fine-tuning and operation; It also should reflect the aesthetics of its cultural heritage; changes with the time of day and year; and, exists in harmony with the local micro-climate and local aesthetics. This definition introduces a new approach to labeling a building as being 'intelligent' by emphasizing the role of occupants' intelligence and the design process as emphasized throughout this study.

2.3.1 Definitions of building intelligence

Attempts to develop a scientific or systematic approach towards the official definition of IBs came only later. Three main bodies associated with IB engineering have suggested definitions for intelligent buildings (Arkin and Paciuk, 1997, p.471; So and Wang, 1999). Part of the definition accepted by the Intelligent Buildings Institute (IBI) in the United States is: "An Intelligent Building is one that provides a productive and cost effective environment through optimization of its four basic elements: structure, systems, services, management and the interrelation between them… the only characteristic that all Intelligent Buildings must have in common is a structure designed to accommodate change in a convenient, cost effective manner”.

The definition adopted by the European Intelligent Building Group (EIBG) is: “An Intelligent Building creates an environment that allows organizations to achieve their business objectives and maximizes the effectiveness of its occupants while at the same time allowing efficient management of resources with minimum life-time cost”.

Another definition of Intelligent Buildings for Asia was adopted by the Asian Institute of Intelligent Buildings (AIIB) in 1999, and is based on an assessment method developed for IBs: “An Intelligent Building is designed and constructed based on an appropriate selection of quality environment modules to meet the user’s requirements by mapping with the appropriate building facilities to achieve long-term building value”.

Although the three major definitions are diverse, they all address occupants’ or users’ productivity, effectiveness and requirements as a common concern when claiming a building as intelligent.

2.3.2 Design Criteria for Building Intelligence

Generally, a building is required to meet a number of limits of acceptability for performance (Rush, 1986, p.234) as illustrated in Figure 2-3. This diagram partially represents the criteria required to establish building intelligence. Based on the definitions above, criteria for designing an intelligent building can be classified into the following:

- User-based criteria; productivity, effectiveness of its occupants, and user’s requirements.
- The second set deals with life-cycle and cost, including long term building value and life time cost effectiveness.
- Aesthetics form another set which includes cultural heritage, harmony with local micro climate and local aesthetics.
- Building performance is the last set, including spatial, thermal, acoustical and visual performance, air quality and building integrity.

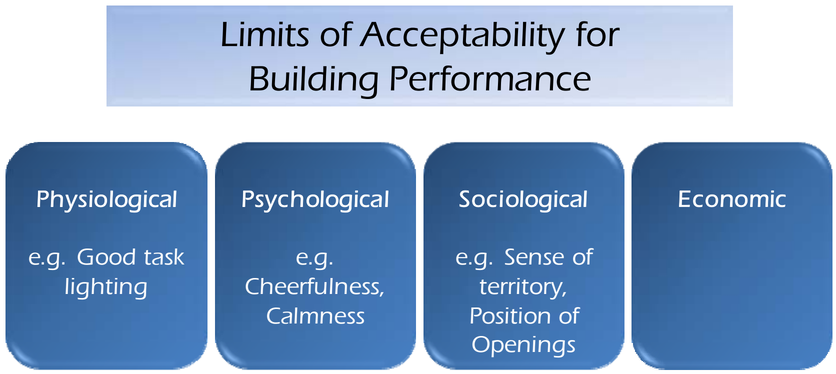


Figure 2-3 Limits of acceptability for building performance

Additional elements and factors necessary to create an intelligent building are listed in the literature. So and Wong (2002, p.288) divide these factors according to the requirements of users into nine “Quality Environment Modules” (QEMs) including environmental friendliness, health and energy conservation, space utilization and flexibility, human comfort, working efficiency, culture, image of high technology, safety and security measures, construction process and structure, and finally life cycle costing.

While Arkin and Paciuk (1997) suggest that the intelligent building is supposed to provide the environment with means for an optimal utilization of the building according to its designation, and that this extended function of a building can be achieved only by means of an extensive use of building service systems. They also suggest that the advantage of IBs lies in the selection of the most suitable systems to fulfill specific goals and in the integration among these systems in order to achieve these goals, both efficiently and economically.

It is generally agreed then that the sole inclusion of high-tech, sophistically controlled service system in a building does not make it an IB. Designing for intelligence thus requires attention to promoting occupants’ performance in the space; if the role of occupants’ requirements and input are considered in the design process, then the building can be labeled as intelligent, since they consequently develop a higher quality of the inhibited environment; “The issue shouldn’t be intelligence in buildings, but intelligent buildings.” (Gregerson, 1994, p.53) As a conclusion, Intelligent Buildings (IBs) are buildings that respond to their surroundings and users' needs, they might themselves be intelligent or they might be the work of an intelligent design process.

2.4 Integrated Building Systems

The main goal of this study is developing the integration patterns of learning technologies and two main systems of an architectural space; the envelope and the interior systems. This section thus offers an overview of the concept of building systems' integration in its generic form.

Integration is seen in the literature as the major component of intelligence in buildings. There is still controversy among IB experts regarding the validity of the equation "Building Intelligence= Systems integration", but it's more widely accepted that systems' integration is a vital part of intelligence in buildings (Arkin and Paciuk, 1997, p.473). Bachman (2003) also suggests that the counter-position of seeing integration as just another word of design is worth pondering.

Although integration is currently one of the most popular topics in architectural research for its proven success in energy, cost and time savings, it has been experienced all the time by architects, either consciously or unconsciously. Since World War II, change has occurred at a revolutionary pace, and for the first time this change has been in the mode of mainstreaming architectural thinking, rather than elements of style, formal expression, and contextual relevance, which highlights the cause of focus on integration (Bachman, 2003, p.vii).

Integration has rarely been a conscious process. The word integration has not had a precise meaning in the domain of building, and for this reason integration has not been consciously sought. Integration results without intension because the criteria that serve as the basis for design are not specific to systems; they are specific to the building as a whole. When criteria come into play through the building, they integrate the physical form automatically (Rush, 1986, p.3). Integration exists as a tangible presence in the materials and machines making up the building. The integration of criteria is evident in the activities possible within the building. Each design decision not only defines the physical combinations and levels of integration materially, but also determines how easily the intended activities can be accomplished.

One goal of integration is to reduce the amount of time, material, and space employed in a building while increasing the number of activities that can take place within it, the result is balance. Thus, conscious thought about integration allows us to recognize and choose our own patterns or change them (Rush, 1986).

2.4.1 Building Systems

Rush's definition of a system is "a coherent set of physical entities organized for a particular purpose. It works when its results correspond to the intentions or goals, based on identified needs, established for it. The success of a system, like that of integration, is evaluated by comparison of the intension with the result, but different methods are used for achieving the result" (Rush, 1986, p.4). While Bachman defines integration as a process "specifically concerned with that aspect of architecture in which technology constantly pushes design possibilities expansively while design assimilation continuously pulls them inward toward a final solution" (Bachman, 2003, p.vii).

Rush defines four distinct building systems (Rush, 1986, p.10, p.318, p.384):

- Structure (frames, shells, slabs, bearing walls and so on): the structure of a building must continually balance a range of forces that vary between natural loads and programmatic loads.
- Envelope: that is the planes defining the enclosure of the space and its outside form.
- Mechanical: heat transfer, power supply, water supply, waste disposal, and
- Interior: defined by Rush as what is visible from inside of habitable building.

2.4.2 The Integration Process

While Buchman (2003) further explains that the concept of integration should include integration in the design process (Software Integration) to discuss issues concerned with unifying art and science by establishing a marriage of design ideas and technical innovation. He also points out the importance of considering integration as a team approach, and the accumulated wisdom of architecture (pp.6-8), which dictates the necessity of including aesthetics, architectural expression and contextual integration in the big equation of building systems' integration.

Generally, hardware and software integration can be summarized into:

Table 2-1 Hardware and software integration

Hardware Integration	Software Integration
Structure (S)	Finance and Management (F)
Envelope (E)	Design Process (D)
Mechanical/Services (M)	Aesthetics (AS)
Interior (I)	Architectural Expression (AR)
Building Site (BS)	Contextual Integration (C)

Degree of integration affects the qualities of flexibility, versatility and changeability. Rush defines different levels of integration as (Rush, 1986, pp.13-14):

1. Remote: do not physically touch,
2. Touching: contact without a permanent connection between the systems,
3. Connected: permanently attached,
4. Meshed: interpenetrate and occupy the same space, and
5. Unified: not distinct.

Integration is established in a building in an attempt to promote occupants' performance. Rush describes six performance mandates or integration goals: (a) spatial performance, (b) thermal performance, (c) indoor air quality, (d) acoustical performance, (e) visual performance, and (d) building integrity (Rush, 1986). While Bachman describes a set of forms for each integration level; for hardware integration the forms are similar to what Rush describes as physical, visual and performance integration, while for software integration the forms are unifying art and science, integration as a team approach, and finally, the accumulated wisdom of architecture (Bachman, 2003, pp.4-8).

This study focuses on the first set of performance mandates to propose integration patterns which address occupants' needs when learning technologies are in use.

2.5 Design Patterns and Pattern Language

In this study, design patterns are considered a method for visually communicating the research findings with decision makers when it comes to integrating learning technologies in the classroom space. The following section thus discusses the nature of these patterns and how to formulate a design language using them.

The idea of a pattern language was first introduced by Christopher Alexander in the late 1970s. Alexander first describes “one timeless way of building” as “a process through which the order of a building or a town grows out directly from the inner nature of the people, and the animals, and the plants, and matter which are in it.” (Alexander, 1979, p.7)

This timeless way of building is based on the fact that our world performs in a structure; this structure consists of certain patterns of events which keep repeating, interlocked with certain geometric patterns in the space (Alexander, 1979, p. 75). In order to gain an understanding of this structure, we must first recognize that a space is governed primarily by what is happening in it; “what matters in a building or a town is not its outward shape, its physical geometry alone, but the events that happen there” (Alexander, 1979, p. 65). Based on this concept, Alexander (1979) defines two distinct kinds of patterns which also apply when defining patterns for learning environments; these are

(a) patterns of events, these are events which keep on happening there most often, and create the character of a place according to the prevailing culture. In learning environments, these are primarily derived by the teaching model adopted and teaching-learning activities repetitively taking place inside the space.

(b) Patterns of space; which define the physical geometry and components of the space. These are the components of the building systems and how they articulate the habitable space.

Each pattern is a three-part rule, which expresses a relation between a certain context, a problem, and a solution (Alexander, 1979, p. 247).

2.5.1 Formulating a pattern language

There is also a fundamental inner connection between each pattern of events, and the pattern of space in which it happens, given that it is just the pattern of events in space which are repeating in the building or the town, and nothing else. Patterns could also be looked at as rules-of-thumb which are part of larger systems which are languages.

As Alexander describes a single pattern as "a rule which describes what you have to do to generate the entity which it defines," he describes a language which connects these patterns as "a system which allows its users to create an infinite variety of those three dimensional combinations of patterns which we call buildings, gardens, towns" (Alexander, 1979, p.182, p. 186). It is recognizable then that all acts of building are governed by a pattern language of some sort.

To formulate this language as it relates to individual projects we must always start with observing and identifying some physical features of the place. Then identify and define the problem. Finally, define a range of extents where this problem exists, or the context of the problem.

Patterns then must be formulated in the form of a rule which establishes a relationship between a context, a system of forces which arises in the context, and a configuration which allows these forces to resolve themselves in that context. It follows a generic form as illustrated in Figure 2-4: "Context → System of forces → Configuration." As relates to the focus of this study, the context is generally a potential integrated design opportunity between learning technologies and one or more components of the envelope or interior system in the learning environment. Systems of forces are sets of design problems and constraints, while the configuration is illustrated in the form of the proposed integration pattern.

Yet, it is hard to be precise in identifying patterns because there is never any one formulation of the pattern which is perfectly exact, which relates to the definition of design problems as wicked problems. Thus, the designer will have to "express and visualize a pattern as a kind of fluid image, a morphological feeling, a swirling intuition about form, which captures the invariant field which is the pattern" (Alexander, 1979, pp. 262-263). This visualization must be followed by a redefinition of the pattern as an entity in order to make it operational, then the designer must be able to draw it, and give it a name; only then the pattern is clearly sharable (pp. 265-267).

Based on these characteristics which describe the language, Alexander redefines each pattern as "an operator which differentiates spaces: that is, it creates distinction where no distinction was before," and accordingly defines a pattern language as "a sequence of these operators, in which each one further differentiates the image which is the product of the previous differentiations." (Alexander, 1979, p. 373)

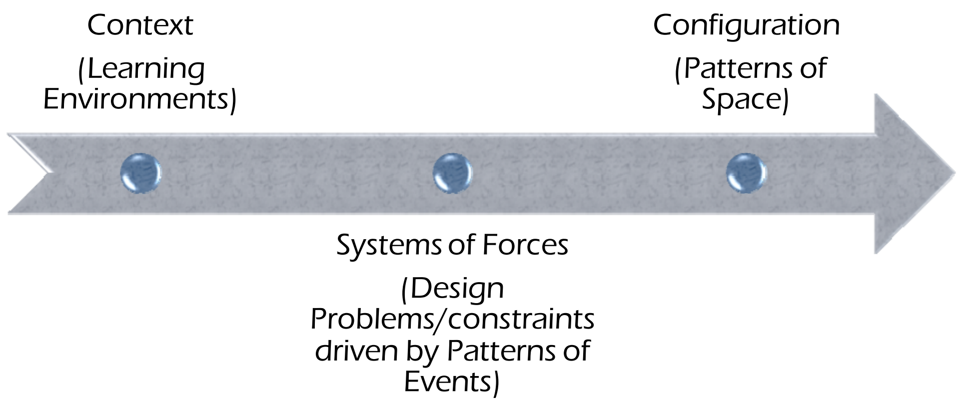


Figure 2-4 Generic rule for pattern formulation

2.5.2 Scales of Patterns

A pattern language covers every range of scale in our surroundings; the largest patterns cover aspects of regional structure, middle range patterns cover the shape and activity of the building, and the smallest patterns deal with the actual physical materials and structures out of which the buildings must be made. A number of more recent efforts have attempted to pick up where Alexander left off as it relates to learning environments as discussed in chapter 3 (Lackney, 1999; Moore & Lackney, 1994; Moore & Lackney, 1995; Nair, 2004; Scott-Webber, 2004). Unlike Alexander's classification of three levels of hierarchy, Moore and Lackney's (1994) set of patterns is organized into four clusters: (a) planning principles, (b) building organizing principles, (c) the character of individual spaces, and (d) critical technical details.

This study is bound within the last two clusters; the character of individual spaces as it pertains to the classroom physical space, and the critical technical details. Unlike previous research efforts which solely reflected architectural and planning variations, patterns emerging from this study are derived primarily by variations in pedagogical practices in the learning environment and the use of relevant educational technologies. Patterns proposed in this study specifically address the building systems scale as illustrated in Figure 2-5.

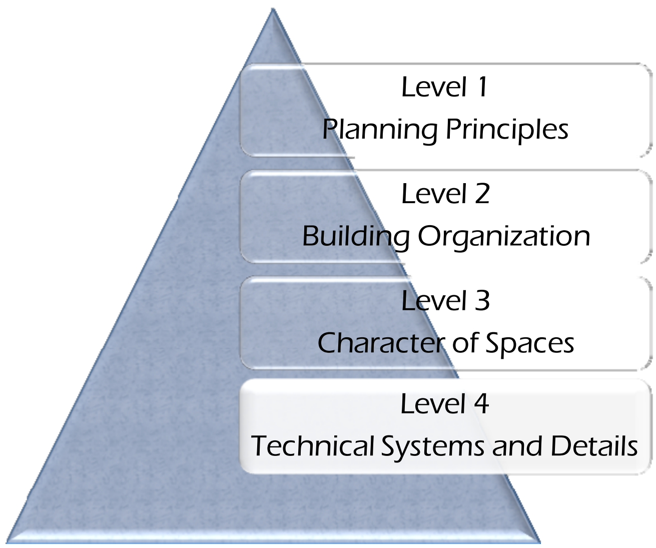


Figure 2-5 Levels of pattern language

CHAPTER 3 CONTEMPORARY PEDAGOGY AND THE DESIGN OF LEARNING ENVIRONMENTS

This chapter reviews different approaches to contemporary pedagogy and their influence on the design of today's learning environments, it also outlines the major pedagogical factors that should be considered in its architectural design, and previews different design patterns for learning environments as presented in the literature. Specifically, this chapter discusses the following topics:

- Four Components of Learning Environments
- Contemporary Pedagogical Approaches
- Designing Technology-Rich Learning Environments
- Design Patterns for Learning Environments

3.1 Four Components of Learning Environments

Previous research efforts conclude that there is positive correlation between the physical environment and students' achievement in their learning experience (Bingler, Quinn, & Sullivan, 2003; Bransford, Brown, & Cocking, 1999; Brown & Lippincott, 2003; Cash, Earthman, & Hines, 1997; Earthman, 1985; Ehrenkrantz, 1999; Khine & Fisher, 2003; Kliment, 2001; Meek, 1995; Moore & Lackney, 1994; Nair, 2003a; Nair, 2004; Sanoff, 1996; Sanoff, 2001; Taylor, 1993). While the traditional classroom still exists, it is encountering continuous changes due to rapid advancement in teaching and learning styles as well as learning technologies.

It is important thus that the design of new learning environments not only addresses efficient physical performance of the building, but also it should motivate students and be sufficiently flexible to be able to host these rapid changes. Sanoff (2001) summarizes the need for a new approach towards the design and planning of educational facilities saying "School buildings ought to be an expression of the fact that exploration and discovery are important parts of obtaining knowledge. Current learning styles and teaching methods suggest the need for a new form of learning environment characterized by different activity settings and small group activities." (Sanoff, 1996, p. 18)

In the research related to performance of school buildings, there is a lack of suggested policies or procedures from the users' viewpoint (Sanoff, 2001). Although a number of efforts have assessed the classroom environment; most studies have stressed features such as lighting, temperature, acoustics, and floor-space per child. Yet, how teachers and students perceive and use the classroom with the provision of learning technologies is still a gap in the research which this study attempts to fill.

In order to gain a better understanding of the nature of learning environments and patterns within them, it is important to learn about each of their major components. Figure 3-1 illustrates the four components of learning environments as proposed in this study and further discusses in the following sections. These components are (a) learning technologies available to support the teaching-learning process, (b) the pedagogical models adopted, (c) the physical environment and its components or systems (d) space occupants and issues like productivity, safety, and comfort.

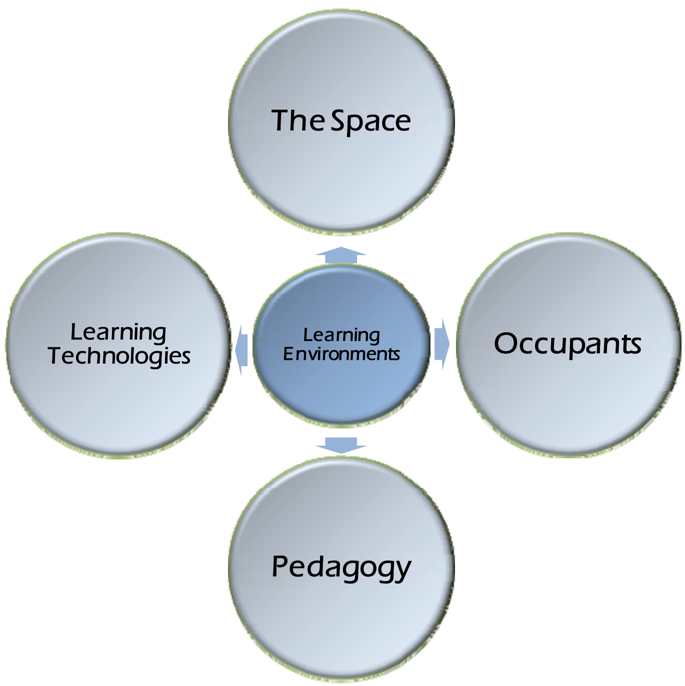


Figure 3-1 Four components of learning environments

3.1.1 Learning Technologies

Studies in the area of learning technologies emphasize the significant, revolutionary role which they play in the teaching-learning experience today. (Burge, 2000; Khine& Fisher, 2003; Kozma, 2003; Morrison & Dede, 2004; U.S. Department of Commerce, 2002). Yet, it should be recognized that any discussion of the role of technology in education is certain to be out of date by the time it is published.

Valentie (2002, p. 54) summarizes the transformation happening in the performance in learning environments saying that the classroom space is highly transforming from being the domain of the professional lecturer to a multimedia-intensive, highly collaborative facility used to produce and consume media-rich materials. Occupancy patterns are thus influenced and consequently the design of the architectural space (Bliss, 1996; Brown & Lippincott, 2003; Dede, 2002; Ehrenkrantz, 1999; Nair, 2003b; Richardson & Wheeler, 2003; Rickards, 2003; Stuebing, Celsi, & Cousineau, 1994).

Also, integrating learning technologies in the teaching-learning process influences curricula and pedagogical practices in the classroom according to students' age and skills (Kozma, 2003). There is a proven positive impact between certain uses of technology and achievement; for example, learning games in the fourth grade mathematics and science, the use of simulations in the eights grade, as well as the use of computer to collect, download, and analyze data in the twelfth grade (Kozma, 2003).

With the introduction of wireless technology, the traditional patterns of events and space are highly altered; wireless technology is seen as the most transformative advancement in educational facilities, and the teacher's role is expected to become coaching rather than lecturing. Communication patterns will enhance students' collaboration, and consequently, digital ties between students, teachers and administration will redefine the organization (Williams, 2003, p.8). At this point of technological advancement, wireless technology is highly influencing findings of this research when it comes to patterns of events and as discussed in chapter 5.

Figure 3-2 illustrates data collected from participants through the initial web-based survey regarding the availability of learning technologies in their classroom space versus learning technologies which they actually use in the teaching-learning process.

Participating teachers emphasize their need for traditional learning technologies such as the white board and projection screens. This need is mostly driven by teaching habits and traditions, their individual preferences, or ease of use. It is also influenced by the teaching model which they adopt.

Teachers in the research sample use wireless technology when it is available in the space, which supports the introduction of mobile lap-top computers next to the desk-top computers which are still considered one of the most used technologies. This has altered the space layout in a number of ways; the most significant is discarding the traditional wide perimeter desktop stations from the space, which was space consuming and with least flexibility when it comes to the activity patterns.

On the other hand, and despite the availability of the smart-board in a number of investigated learning environments, the traditional white board still represents the most used learning technology. Some interviewed teachers refer that to the large surface area it offers, and its ability to accommodate layers of text. Others still use it as the traditional means to communicate information with students, in addition to the fact that it does not require frequent electronic connections, adjustments and alignments.

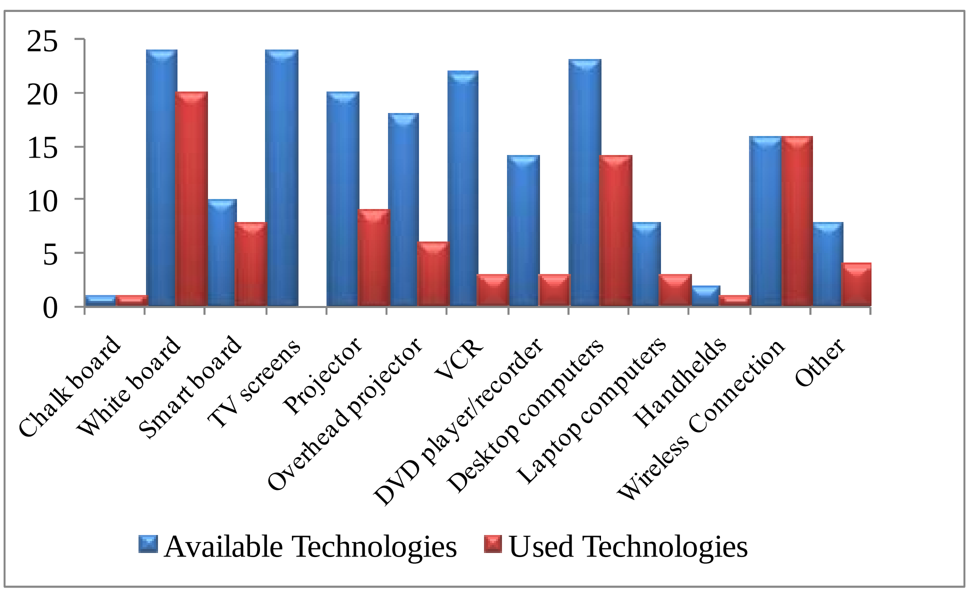


Figure 3-2 Available versus used technologies

3.1.2 Pedagogy

While architects and facility planners are focusing their efforts on designing energy efficient, high performance buildings to meet benchmarking and labeling requirements, more emphasis is needed on designing instructionally high performance schools.

Current research in education suggests that teachers need to become aware that each student acquires a different learning style. Understanding learning styles involves understanding behaviors when approaching, or while involved in different learning experiences and when applying new information and skills in real life situations (Sarasin, 1999). More progressive teaching approaches and activities are being introduced in order to accommodate these diverse learning styles and new activities in the classroom are being encouraged. Such approaches, as discussed in the following sections, include collaboration, interactive problem-solving, learning through inquiry, project-based, lecture-based, multidisciplinary, and project-based learning.

A major part of the accommodation needed for these new activities can be established through the physical environment. A classroom space thus should be flexible enough to support different teaching modes like lecturing, large group, small group, and individual teaching instances (Stuebing and Cousineau, 1994).

The study of learning environments in this research is directly correlated with the pedagogical practices taking place within them; patterns of space are driven by patterns of events. The primary purpose of incorporating innovative architectural solutions in the planning of learning technologies is that the spaces will be able to support a variety of progressive pedagogical models which have been rapidly developing in the world of education. Figure 3-3 illustrates a spectrum of these models ranging between the teacher-delivered, direct models, towards the social models and finally the student-based, radical models. The following sections offer a description of teaching practices labeled under these models and represent the researcher's organization of different interpretations and approaches of teaching models as presented in the literature (Center of Educational Technologies at Virginia Tech, 2004; Davis, Sumara and Luce-Kapler, 2000; Gredler, 1997; Joyce and Weil, 1986).

Classification of any teaching-learning approach under a certain pedagogical model first depends on whether or not the teacher allows students to formulate their own opinions of a case by promoting activities like group-coordinated research activities, debate, or simulated decision making. The key difference is the extent to which a teacher directly leads the student versus promoting activities through which students can lead themselves and develop valuable reasoning skills in the process.

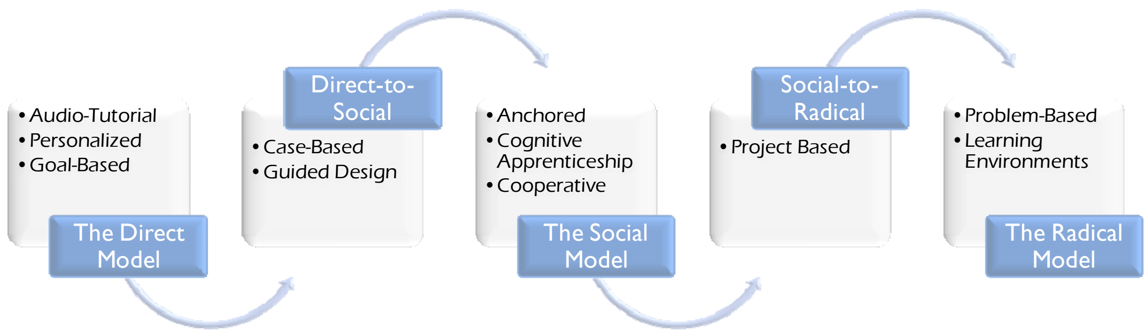


Figure 3-3 A spectrum of pedagogical models

3.1.2.1 Direct Instruction (Top-Down/ Teacher Delivered Models)

These models involve the students as recipients of information with minimum individualized contribution in the teaching-learning process. They include (a) the audio-tutorial approach, where course materials are pre-structured, segmented, and presented to single learners in the order and manner deemed most appropriate by the instructor or an instructional designer. (b) The personalized system of instruction, which practically fits in several paradigms, but mostly fits with direct instruction by requiring students to work on course modules independently. Finally, (c) goal based scenarios, where teachers identify a specific set of skills to teach via a goal-based scenario, then embed that skill learning in a task, activity, or goal that the student will find interesting or motivational.

Moving towards a more social interaction, case-based learning and guided design start to emerge; (a) case-based learning is a flexible model, where the instructor uses leading questions to direct students toward a moral or process he or she deems "correct". While (b) guided design can reflect direct instruction by requiring students to read or work on pre-specified content segments or problems.

3.1.2.2 Social Models

Social models rely on students' self apprehension in the learning process, and as such, they fall between anchored instruction, cognitive apprenticeships and cooperative learning. The first social model (a) anchored instruction lies within the social constructivist paradigm where small groups work together to understand and solve realistic problems. Anchored instruction is most closely related to the goal-based scenario model. While anchored instruction may also resemble problem-based learning (PBL), it is less open-ended. Similarly, (b) cognitive apprenticeships are also situated within the social constructivist paradigm. Within this model, students work in teams on projects or problems with close scaffolding of the instructor. Students encounter learning tasks which are slightly more difficult than they can manage independently requiring the aid of their peers and instructor. Finally, (c) cooperative learning, which is also situated within the social constructivist paradigm, invites students to work on projects or problems in teams with both personal and team accountability for conceptual understanding.

Constructionism, or project-based models, on the other hand lies between the social and radical constructivist paradigms. The model suggests students learn by creating materials. Unlike constructivist models that provide students with cases and context-bound problems, constructionism involves students in the creation of their own cases or problems. Students may work alone or in teams, but their efforts are scaffolded closely by the instructor.

3.1.2.3 Student-based (Radical/Bottom-Up) Models

Students within these models are primarily considered self-learners. (a) Problem-based learning (PBL) which is situated approximately half-way between the social and radical constructivist paradigms, as explained above, utilizes student groups, but each group member is also responsible for independent research. Further, the role of the instructor is considerably less direct in problem-based learning than in other constructivist models. Students are encouraged to struggle and construct their own mental model of course concepts with only occasional "life-lines" from the instructor when concept processing falls off-track. Problem-based learning is most similar to case-based instruction, but in its purest form, PBL is more open-ended. (b) Learning environments are typically constructivist in nature, engaging learners in "sense-making" or reasoning about extensive resource sets. Learning environments typically include four components: an enabling context, resources, a set of tools, and scaffolds (Hannafin, Land, & Oliver, 1999). Authentic or realistic contexts are provided to motivate learners, and typically take the form of complex, full-scale problems representative of real-world tasks. A truly open-ended learning environment would involve students in independent research to find and select their own relevant resources. A full set of tools should be provided to help learners process information, manipulate data, and discuss the data.

Chapter 4 offers a classification of research participants within this spectrum of teaching models according to their input during the data gathering phase. Most participants are found to practice direct-instruction or direct-to-social models of teaching. Thus, patterns of events taking place in their learning environments are not highly diverse and do not generally offer extreme patterns of space.

3.1.3 The Physical Environment

A learning environment is any space; whether it is a built enclosure, an outdoor area or both, which hosts the teaching learning activities. In this study, only enclosures are considered for analysis. Similar to any other architectural enclosure, it is defined by the envelope planes and contains a number of integrated systems as described in chapter 3.

A number of interwoven issues govern the design of contemporary technology-based learning environment. These issues can be classified into spatial, social, environmental, or technological as discussed in the following sections (Brubaker, 1998; Ehrenkrantz 1999; Richardson and Wheeler, 2003; Stuebing and Cousineau, 1994; Williams, 2003).

3.1.3.1 Spatial

These are issues concerned with space definition, layout, zoning and adaptiveness of the space to different activities. They are also influenced by future technological changes, connectivity to the outdoors, multiuse and integration among different systems and learning technologies.

Stuebing and Cousineau (1994) recommend that learning environments have to be learner-centered, active, multi-sensory, multi-media and individualized environments in order to support the various teaching approaches which might take place in one space at a time. Flexible layout is also a concern of high priority since the educational setting accommodates many different kinds of activities; whether of short or long durations and may require special 'set-aside' spaces. Some are planned and others are spontaneous, and all of them require a highly flexible space. In that sense, flexibility means that the space provides a diversity of settings for learning, not only different furniture permutations.

3.1.3.2 Social

The described environment is an active and social one. Students work together, and teachers and students often share 'coaching' responsibilities. This student and teacher collaboration can be accommodated by providing flexible and varying furniture layouts and clusters. The concept is to create a multidisciplinary setting with high communication potential. In addition, remote technologies also offer a higher potential for such social communication within the learning environment through wirelessly controlled devices.

3.1.3.3 Environmental

Design of the acoustical, thermal, and visual environments are major issues when we deal with occupants' comfort in the space. The space being highly populated with different activities and equipment should be designed for sound attenuation, and might need to include separate support rooms for faculty, special projects, or isolated small group projects. Thermal loads from computers and other equipment integrated in the space are a design concern when it comes to HVAC loads, thermal comfort and energy efficiency. Occupants' visual comfort is another goal when integrating learning technologies in the space. It depends on the spatial qualities of the room such as room proportions and location of openings, as well as the visual qualities of the display screens.

3.1.3.4 Technological

Technology should not be used as an activity in itself, but rather should be one of many tools used in the learning process. The physical environment thus should facilitate performing multiple activities with easy access to learning technologies. Access points to network cables and electrical power around the periphery of the room restricted the organization of the educational setting in the past. Mobile or remote digital technologies nowadays offer many other alternatives, where the setting can be highly flexible and occupants can be located freely around the space.

3.1.4 Occupants of the Space

The process of change in a learning environment is controlled in part by teacher belief systems that limit the number of possible options for change. These beliefs are cultural, experiential, and historical. Thus, learning environments which supported new teaching models have always encountered performance failures since teachers were not usually ready for change and they resisted everything new that the classroom presented (Ehrenkrantz, 1999; Brubaker, 1998, p.20).

In a technology-based learning environment, teachers face a new role; to manage the learning environment and to coach and motivate students. Technology and the physical environment should still support this change by providing individualized, small team, as well as group instruction and giving students the opportunity to progress at their own pace. Students, on the other hand, are expected to spend more time in “activities that simulate real world experiences as opposed to the passive transfer of information”; they have to become more active participants in the learning process (Richardson and Wheeler, 2003, p.12).

Teaching-learning activities form patterns of events which primarily derive patterns of space required to develop a spatially successful learning environment. Thus, how teachers and students interact with each other and learning technologies highly influence decisions of integrated design.

3.2 Design Patterns for Learning Environments

A number of research efforts have developed design patterns for educational facilities (Lackney, 1999; Moore & Lackney, 1994; Moore & Lackney, 1995; Nair, 2004; Scott-Webber, 2004) based on the pattern language first introduced by Christopher Alexander (Alexander, 1972; 1979; Alexander, Ishikawa, & Silverstein, 1977).

A number of patterns for planning a technology-rich learning environment have been discussed in the literature. These patterns take into consideration a variation of pedagogical practices and how they influence the design of the space. They also address design patterns at either the planning level or the building organization level as discussed in chapter 2.

They define 9 primary patterns which describe performance within a learning environment. Each of which include a second level of patterns describing activities within the space (patterns of evernts). Although these patterns are not directly considered in the analysis process of this study, they form the theoretical background upon which the design of the data gathering instruments is based. These patterns as discussed in the following section are: lifelong learning, social function, personalization, multi-disciplinary, teaching-learning modes, new paradigm school buildings, supporting units, security, and technology tools

3.2.1 Lifelong learning

Education is a long-life process which starts at birth (Hinrichs, 2002; Kliment, 2001; Nair, 2003a); each stage has its own needs which are supported by a variation of learning technologies. Two important consequences for the lifelong learning concept emerges; one is that the emphasis on education shifts to teaching learning skills rather than disconnected content, another aspect is provision of opportunities of continuing education for adults (Nair, 2003a).

Variables which are related to this area are primarily concerned with (a) teaching-learning skills, and (b) life-skills (conflict resolution, character education, teaching wisdom). These variables directly influence the activities taking place within the physical boundaries of learning environments and learning technologies in use.

3.2.2 Social function

Activities within schools have educational as well as social aspects, yet quality in both is important for the operation and development of schools; not only learning environments serve to deliver the curriculum, they also are the places where students spend time, and this aspect too should receive attention. Students need to feel a sense of belonging, common purpose and loyalty to the smaller unit. Social areas in the school are important to create an overall atmosphere that students can identify and help them feel ownership of the environment (Kliment, 2001; Nair, 2003a).

On the other hand, cultural diversity in schools provides a strong opportunity to create an environment which enhances life long learning as well as social function. School design should support activities based on cultural exchanges and consequently student-student learning opportunities are encouraged.

Variables influenced by social function in learning environments include (a) privacy, (b) personal space, (c) social grouping, (d) cultural diversity (e) participation, (f) learning communities, (g) learning advisories, (h) activity pockets, and (i) common themes (academies)

3.2.3 Personalization

"Schools need to do more than just select students according to their cognitive abilities. They need to become places where diverse talents are recognized and nurtured." (Nair, 2003a, p. 3)

Students' individual learning styles play a significant role in shaping the learning environment; numerous studies have addressed this issue from varying perspectives (Bransford, Brown & Cocking, 1999; Magolda, 1999; Sarasin, 1999). Within Howard Gardner's theory of multiple intelligences, intelligence is defined as the ability to solve real-world problems or to do something valued within one's culture. This theory suggests personalization (Kliment, 2001, pp.4-5). These intelligences are described as (a) linguistic (the word player), (b) logical or mathematical (the questioner), (c) spatial (the visualizer), (d) musical (the music lover), (e) bodily or kinesthetic (the mover), (f) interpersonal (the socializer), and (g) intrapersonal (the individual). The teaching-learning system might have bias towards, and support certain intelligences. Yet, if the classroom can be adapted to support this diversity in intelligences, all students will have equal learning opportunities, which is a significant teaching goal.

Emerging variables are (a) individual learning style, (b) ability to master educational standards, and (c) methods of delivering education, which directly addresses research questions posed within this study.

3.2.4 Multidisciplinary (Learning boundaries)

There is a strong call for non-divided teaching experience through the traditional school day. Students should be able to learn in a “real-world” fashion, which does not divide education into separate “learning blocks”, like science, art, mathematics …etc.

More progressive learning models are even extending the learning experience to nature and extending the physical boundaries of learning environments to the outdoors. In an outdoor learning experience students are able to utilize the majority of their sensory and emotional skills, which makes the experience more “authentic”. Despite the fact that this study is limited to the physical boundaries enclosing the learning environment, connecting it to the outdoors significantly affects design decisions of the envelope and the interior systems.

When it comes to designing the physical space to enhance this dimension, the following variables are recognized: (a) multidisciplinary rooms, (b) creativity and the aesthetic component, and (c) outdoor learning.

3.2.5 Teaching-learning modes

A number of teaching-learning activities are likely to take place in the classroom. The space should support these varying conditions efficiently and rapidly. Such activities might range from the direct model to the social model and the radical, student-based model.

It is even more likely in today’s classroom that these activities are based on distant education and virtual environments where different considerations should be taken into account regarding the physical setting, timing, and technology tools.

Variables which emerge under this category directly influence findings of this study and include (a) flexibility, (b) seating arrangements, (c) connections, (d) visualization, (e) level of contact, (f) activity pockets, and (g) access.

3.2.6 New paradigm school buildings

Previous research efforts suggest that successful learners need a variety of spaces in the educational facility (Bransford, Brown & Cocking, 1999; Ehrenkrantz, 1999; Fielding, 2004; Kliment, 2001; Nair, 2003; Sanoff, 1996; Taylor, 1993). New paradigm schooling programs, according to Nair (2003, pp. 17-18), are best conducted in non-traditional learning settings. Yet, the reluctance to break from tradition must be seen in light of the fact that the majority of learning environments have already been built, and are currently in use.

Smaller schools have proven to function more efficiently when it comes to delivering education to students (Bliss, 1996; Fielding 2004; Kliment, 2001; Nair, 2003a). This approach successfully corresponds to the personalization concept presented above, as well as the collaborative and peer learning approaches. Educational facilities adopting this design approach divide the building into self-contained learning clusters hosting smaller groups of students. These clusters are repetitive within the building mass.

This pattern studies the planning scale, yet the variables concerned influence the findings of this study at the systems' scale. These are (a) design diversity, (b) activity zones, (c) multipurpose learning studios, (d) access to non-traditional learning settings ('project rooms', 'resource areas', 'learning streets', 'flow rooms' and 'places to think') (Nair, 2003), (e) flexibility (living architecture), (f) open environment, (g) teachers' working spaces, (h) houses of learning, (i) learning clusters, (j) activity pockets, and (h) size of learning community.

3.2.7 Supporting units

Many proven design failures have been caused by the carelessness in designing supporting units to the main learning space. With the increasing transformations in the learning environment, especially when it comes to using educational technologies, and designing and utilizing classrooms as learning studios, students and instructors are spending more of their time inside the classroom space, where they need more space to keep their personal belongings safely, and with quick and adequate access.

With the change in usability patterns inside the classroom space, individuals will be in need for spaces within their learning environments to practice their privacy and be able to relax, and feel safe about their belongings. Thus, patterns which address these issues are: (a) storage, (b) relaxing areas, (c) privacy, and (d) comfort.

3.2.8 Security

Security has become a priority in designing today's educational facilities. With the ever-increasing introduction of technologies in the building, and the interactive nature of buildings as building tools, students' supervision and monitoring has become a critical issue (Kliment, 2001; Nair, 2003a). It should be taken into consideration that a balance between the role of the teacher as an instructor versus his/her role as a director, or moderator has to be established.

Security principles include (a) safety, (b) monitoring, (c) supervisable circulation paths, and (d) teacher control.

3.2.9 Technology tools

As discussed earlier, technology is a major variant for this research. Nair (2003a) describes today's classroom as a multi-zone, interdisciplinary, hands-on learning studio, where different modes of learning are occurring at the same time. He points out that from a technology standpoint, this kind of learning studio requires that some or all students be able to simultaneously access the school's network and the Internet to conduct independent study and for group projects. These current trends call for looking at technology as liberators (Kliment, 2001), especially given the emerging wireless technologies.

Morrison and Dede (2004) state that any technology or medium can be implemented with a wide spectrum of pedagogies, such technologies currently range between multimedia, image processing, digital media as well as audio-visual and web-based technologies. Dede (2002) further anticipates the emergence of more interactive technologies to support learners through their experience; he classifies these technologies as the familiar (world to the desktop), interfaces for ubiquitous computing and finally the multi-user virtual environments interfaces (MUVE).

In implementing a technology plan, decision makers face an array of issues. Kliment (2001, p. 146) states that such decisions have to do with how learning and administration functions will be served, what technologies will be provided, how many users the network must serve now and in the future, and how information will be secured. Location and types of new wiring are other issues. Yet, Nair (2003b) calls for fewer high-technology specialty labs due to the rapid rate of technology change. He suggests that this problem can be addressed by designing spaces with generalized, mobile furnishings and equipment with multiple uses.

The following principles thus emerges following the pattern of technology tools, and they also influence findings of this study; (a) mobility, (b) access, (c) wireless versus wired (Technology as liberators), (d) comfort, (e) speed, (f) visibility, (g) multiple-use specialty labs, and (h) interactive building systems.

3.3 Participation in Design

The development and use of design patterns, which is the goal of this study, takes the form of a collaborative dialogue between researchers and practitioners from both the architectural and educational professions. Participants in this process should share a common pattern language which makes spaces alive. (Alexander, 1979; Alexander, Ishikawa, & Silverstein, 1977; Moore & Lackney, 1994; Moore & Lackney, 1995)

Alexander (1979, p. 209) supports the possibility of such collaborative process stating that "the patterns, which repeat themselves, come simply from the fact that all the people have a common language, and that each of them uses this common language when he makes a thing" (Alexander, 1979, p. 209). Alexander further explains that the enormous repetition of patterns, which makes up the world, comes about because the languages which people use to make the world are widely shared. (p. 209-210)

An observer or interpreter thus is able to recognize this common language through a deep understanding of how people utilize the space, as well as knowledge of the problems that exist in this space in order to identify the invariants which solve the problem. Sometimes invariants can be identified by starting with a set of positive examples, and at other times, by starting from the negative examples, and resolving them. "In all these cases, no matter what method is used, the pattern is an attempt to discover some invariant feature, which distinguishes good places from bad places with respect to some particular system of forces." (Alexander, 1979, pp. 257-260)

In order to establish this process in this study, qualitative data is gathered through a number of data gathering modes as discussed in chapter 4. These modes question the teacher's pedagogical approach, teaching and learning activities within the space (patterns of events), as well the technologies available and technologies needed to support his/her particular practices, and also question how well the spatial characteristics of the room supports and contains such technologies (patterns of space).

The findings are then translated into pattern language which can be communicated between designers and facility planners, as well as teachers and students as users of the learning environment, and also with other stakeholders and community members.

CHAPTER 4 RESEARCH DESIGN

As described by Churchman (1971), inquiry is an activity which produces knowledge; such that it “makes a difference in and of itself” (p. 8-9). Within this activity, knowledge resides in the user and not in the collection of information; it is how the user reacts to a collection of information that matters, and to be knowledgeable “one must be able to adjust behavior to changing circumstances.” (p. 10)

As pertains to the design problem addressed by this research, users of learning environments are possessors of knowledge. From a methodological stand point, what matters is how users react to a situation of data collection as prescribed for this study. By observing and interpreting such reactions, it is only then possible to transfer this knowledge to the research and design worlds.

This chapter thus reviews methods of data gathering, organization and analysis. It also offers a definition of the selected research sample and the research process.

4.1 Research Methodology

This study is qualitative in nature and is based on data gathered in interviews with teachers at their learning environments. In general, qualitative research is described as being “multi-method in focus involving an interpretive, naturalistic approach to its subject matter.” Things are studied in their natural settings, where researchers attempt to make sense and interpret phenomena in terms of meanings people bring to them. It is characterized by being holistic, conducted through prolonged, open-ended contact, relying on human subjects as measuring devices due to the relatively little use of standardized measures, and the principle mode of analysis in this case is through words, sketches and observations (Groat and Wang, 2002, pp. 176-212).

A qualitative research design is completed in four phases; (a) data collection, through the different modes of data gathering which are introduced in the following sections of this chapter; (b) data reduction, which involves coding and graphical interpretation; (c) drawing conclusions and verification, primarily through triangulation of multiple data sources; and finally (d) data display, which is concerned with presenting research findings.

The research questions are organized to address the four components of learning environments. They aim to understand and interpret the performance within learning environments when learning technologies are in use:

1. Participants-by-Pedagogy: (a) What are the pedagogical practices adopted by the research sample? and, (b) How do these practices influence decisions regarding learning technologies and the learning environment?
2. Participants-by-Technologies: (a) Which learning technologies are needed to support pedagogical models? and (b) What architectural decisions should be considered for efficiently integrating learning technologies with other physical architectural systems in the space (the envelope and interior systems for the purposes of this study)?
3. Participants-by-Space: How do architectural systems integrate in a technology-rich learning environment?
4. Participants-by-Occupancy: How can the design of the learning environment support such practices? How does the space respond to patterns of events?

4.2 Role of the Researcher

This research primarily considers the role played by users of learning environments in the decision-making process. This section discusses the researcher’s role in understanding and interpreting users’ perception of their performance in the space when learning technologies are in use.

Design in general falls under the category of “Wicked Problems” (Blum, 1996). Given the fact that there is no one ‘best solution’; each problem thus has a number of solutions. These solutions are either facts (patterns of space) or attitudes (patterns of events) which are interpretations of the facts, traditional and customary approaches, and value judgments. Thus design and planning decisions are by nature biased and depend on values of decision-makers (Sanoff, 1992, pp.59-60).

This bias is also dictated by the nature of the qualitative paradigm. Rossman and Rallis (2003) propose that qualitative research is “quintessentially interactive,” where the qualitative researcher is taken into a complex and varied interactions with the participants (p. 35), unlike experiments or surveys where participants interact with standardized sets of procedures or written questionnaires. Thus, the knowledge constructed during the study is interpretive, where the researcher makes meaning of what he learns as he goes along.

Interpretation plays a significant role in data analysis in this study. Groat and Wang (2002) discuss interpretivism as a paradigm of applied phenomenological qualitative research. Schwandt (1998) describes the defining quality of this tactic as “the shared goal of understanding the complex world of lived experience from the view point of those who lived it” (p. 114). On adopting this tactic, participants are asked to express their thoughts, ideas and feelings about the research subject in graphic form. The researcher is then responsible for “interpreting” this language.

The broader goal of this study thus is to extend the paradigm and current states of knowledge of the general audience by building on the information provided by the participants’ state of knowledge in relation to the research questions through interpretation. The findings are then translated in the form of themes and patterns which will then be communicated with the industry as well as other stakeholders involved in decisions concerning learning environments.

The discussion of the architectural component in this study is primarily dictated by the researcher’s architectural-engineering educational and professional backgrounds. The analysis process thus is biased towards methods known in this discipline rather than the field of education. Also, pedagogical practices and teaching models presented throughout this research are significantly different from those which the researcher has practiced in her learning experience in the middle-east area. Thus the data gathering process required thorough investigations prior to implementation of the research instruments to cover this gap between the American model of teaching and other models implemented at the researcher’s origin.

4.3 Research Sampling

The sample of learning environments are selected from Academic-Year Governor’s schools in Virginia hosted in their own facilities, as well as science and technology schools falling within a 300-miles-radius from the Virginia Tech campus.

The choice of Academic-Year Governor's Schools is based on their use of innovative and progressive teaching models as well as their employment of advanced learning technologies. This is also supported by faculties who are selected based on advanced degrees, professional experience, and training and/or experience with gifted high school students. Most teachers have the gifted add-on endorsement that represents post-graduate training in gifted education, and several are certified through the National Board of Professional Teaching Standards. According to their official website, each school is responsible for providing staff development to extend its teachers' knowledge and use of innovative teaching strategies, technology, and contemporary subject matter.

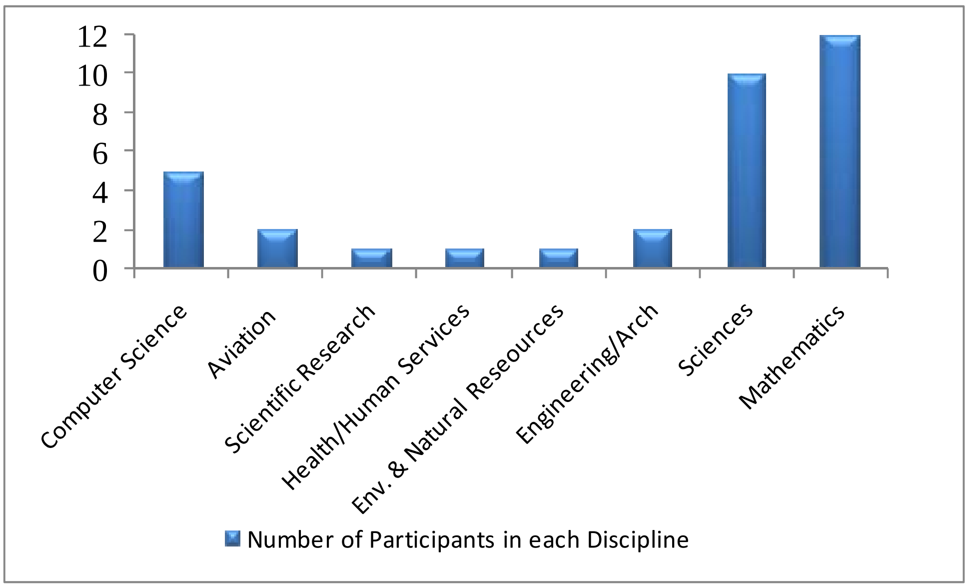
Governor's schools generally serve students starting at ninth grade. At this level of education, students should have fully developed their cognitive, physical, emotional, social, and linguistic skills (Kliment, 2001, pp. 2-3). Bransford, Brown and Cocking (1999, p. 120) argue that students at this level need to understand the current state of their knowledge and to build on it, improve it, and make their own decisions. They also expect to use and to learn cutting-edge technology during their learning experience. Accordingly, successful teaching practices at this level should utilize a wider scope of teaching modalities in order to address students' needs and capabilities at this level, ranging from direct instruction to radical teaching models; a variation which this research seeks.

The sampling criteria applied to seven schools which were contacted during Spring semester of 2005 and were invited for participation. Four schools got involved in the study; including three academic-year governor schools and a center for applied technology and career exploration. Twenty five teachers fully participated in the research procedures. One or more of the following modes of contact with research participants were employed in the duration of the study:

1. Personalized electronic mails to school directors.
2. Personalized phone calls to school directors.
3. a) Electronic mailing forwarded to teachers through school directors.
   b) Individualized direct electronic mail messages with teachers.

4. On-site presentations to faculty at the school facility, conducted by the researcher.

The sample of teachers is diverse as well as the disciplines they teach including sciences, mathematics, computer science, aviation, scientific research, environmental and natural resources, health and human services, as well as engineering and architecture. The number of participants in each of the discipline covered by the research sample is illustrated in Figure 4-1. The researcher was able to identify different pedagogical practices through web-based surveys and one-to-one interviews as described in the following sections.



Note: Sciences include anatomy, physiology, chemistry, biology and earth sciences

Figure 4-1 Distribution of research sample according to discipline

Table 4-1 represents participants' demographics according to their input in the initial pre-study web-based survey as will be explained in the following section.

Table 4-1 Participants' demographics

Participants	**Discipline**	**Age**	**Gender**	**Grades taught**	**Number of years in teaching experien-ce**	**Average number of students in current class**
Teacher (1)	Computer Science	37	Male	10-12	14	10
Teacher (2)	Mathematics	30	Male	9-12	8	15
Teacher (3)	Anatomy/Microbiology	55	Male	--	--	--
Teacher (4)	Chemistry/Physics	61	Male	9-12	36	15
Teacher (5)	Mathematics	38	Female	12	17	9
Teacher (6)	Physics	63	Male	11-12	--	26
Teacher (7)	Research/Anatomy	--	Female	11-12	38	25
Teacher (8)	Mathematics	44	Female	11-12	9	24
Teacher (9)	Mathematics	59	Female	11	15	25
Teacher (10)	Aviation & Aerospace	56	Male	8	10	21
Teacher (11)	Aviation & Aerospace	51	Female	8	27	25
Teacher (12)	Health & Human Services	37	Female	8	18	20
Teacher (13)	Science	46	Female	8	21	24
Teacher (14)	Engineering & Architectural Design	--	Male	8	8	20
Teacher (15)	Environmental Sciences	--	Male	9-12	29	22
Teacher (16)	Chemistry	36	Female	9-11	10	16
Teacher (17)	Mathematics	43	Male	9-12	6	15
Teacher (18)	Biology & Biotechnology	59	Male	11-12	30	15
Teacher (19)	Chemistry	63	Female	10-12	41	14
Teacher (20)	Mathematics	47	Female	10-12	24	15
Teacher (21)	Mathematics	30	Female	10-12	7	17
Teacher (22)	Mathematics	60	Female	9-11	37	12
Teacher (23)	Mathematics	60	Male	9-11	11	15
Teacher (24)	Computer Sciences	63	Male	--	--	--
Teacher (25)	Physics & Computer Applications	57	Male	9-12	35	17

4.4 Data Collection and Verification

To address the research questions, a number of data collection modes were employed in the duration of the study.

4.4.1 Initial survey

Participants were asked to complete a web-based survey before the scheduled one-to-one interview (Appendix A). The survey questions three major data sets (a) participants' demographics, (b) learning technologies available and preferences of use, and (c) teaching modes and personal teaching beliefs.

4.4.2 Teachers' interviews

Through open-ended interview questions, teachers were asked to reflect on their teaching practices in the learning environment, their experiences with using learning technologies, how the space supports, or not, the teaching-learning process and different activities taking place in the classroom.

The interviews lasted between 30 to 45 minutes at each learning environment. Each teacher participated in the following procedures in the duration of his/her interview;

- Image narration, where they were asked to describe activities which usually take place in the classroom while capturing digital images of the space relative to the incidents they describe, this narration was audio-tape recorded. These images are intended to capture patterns the space as they relate to patterns of events.
- One-to-one interview: participants were then asked to respond to a specific set of interview questions (Appendix B), the interview protocol focuses on activities within the boundaries of the learning environment and modes of using learning technologies.
- Graphic presentation: participants were asked to graphically represent the layout of their classroom in order to illustrate how the space actually functions and how it "should function" when learning technologies are in use. Figure 4-2 represents an example of a teachers' graphical perception of how her classroom should be as opposed to its current situation, where she proposes a clustered layout rather than a linear layout for the furniture in her space to enhance collaboration and monitoring.

4.4.3 Post-study web-based survey

The main purpose of this follow-up survey (Appendix C) is member-checks and verification of research findings. Participants within the three teaching models were asked to prioritize patterns which emerge from the study according to their spatial needs and teaching practices in verification of the research findings.

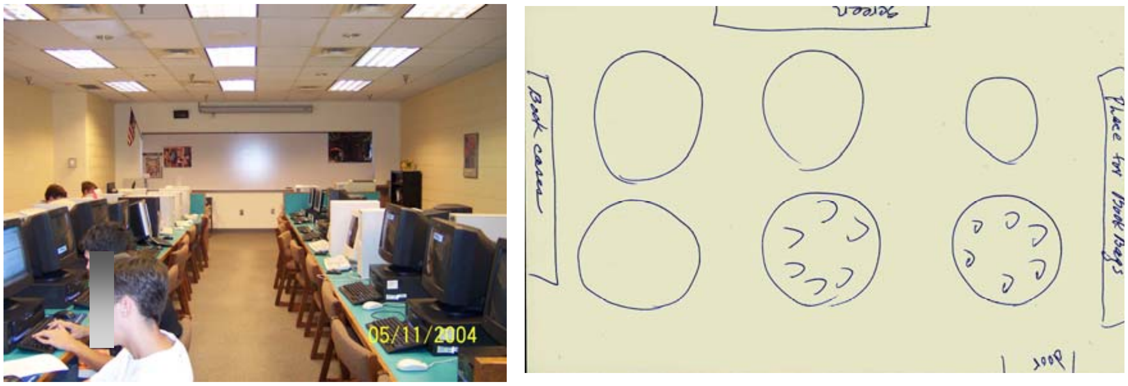


Figure 4-2 Current linear layout of computer lab versus proposed clustered layout

Figure 4-3 represents number of responses received to each mode in the duration of the study.

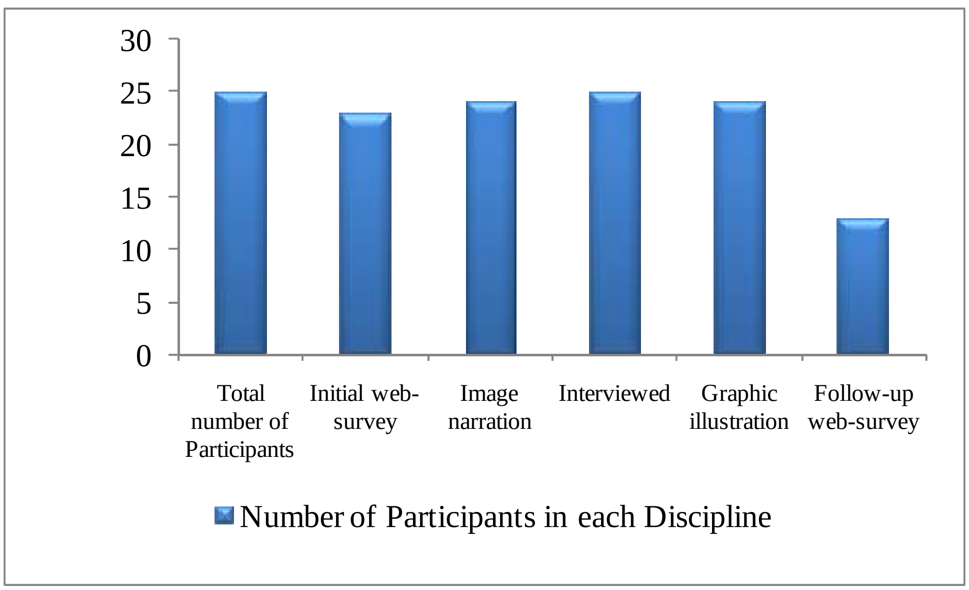


Figure 4-3 Number of responses to data gathering modes

4.5 Data Organization and Reduction

The following sections describe the processes of data organization and reduction. In that, data collected from participants was organized into data matrices to form smaller chunks of data. Participants were also classified according to their teaching style for data reduction.

4.5.1 Data Matrices

Data gathered from participants is organized in four participant-by-question data matrices which reflect the four components of learning environments (pedagogy, technology, space, and the occupants) as discussed in chapter 3, and address the primary research questions asked.

The first column heading in each matrix identifies specific categories of responses to the research question according to the data collection mode employed. These categories have either emerged from the literature or during the data gathering phase. Exact quotes and data input were entered in the cells next to the appropriate category. An example of data matrices is illustrated in Figure 4-4. These matrices are:

1. Participant-by-pedagogy; organizes data about course-specifics, teaching-learning activities and individual pedagogical approaches. This matrix provides information required to classify each participant under the teaching model he or she adopts and gives an understanding of the patterns of events occurring in the space.
2. Participant-by-technologies; organizes data gathered concerning which technologies are available versus which are actually used, ways of monitoring, issues like mobility and access, visibility issues which occupants encounter when using them, as well as typical modes of use (pattern of events).
3. Participant-by-space; these summarize data collected regarding the architectural space in its current shape and what modifications participants suggest. This matrix offers an understanding of patterns of space at the level of space organization. Data is organized according to spatial concerns such as flexibility, access, space layout and proportions, support spaces, connection to adjacent spaces, size of learning groups, activity patterns inside the space, and issues with visibility and lighting.
4. Participant-by-occupancy; primarily describe issues like individual preferences, teacher-student interactions and student-student interactions. These matrices are also used to gain an understanding of patterns of events taking place in the teaching-learning environments.

Teacher (2)- Mathematics			
Access	*"The projector should actually hang from the ceiling, taking it out from the way."*		G2
Space Layout/Proportions	*"I've got basically all of the desks set up where the focus of the room is this particular board [smart board], that's where I need their attention focused."*		N2-1S
Size of Learning Group	15 students		W
Visibility/Lighting	*"When the sunrises, and during morning classes... I might get a little bit of glare on my computer screen, and as it goes up it washes out the board."*		I
	"If it s especially a bright day outside, I might put the lights down, but I usually put them on all the time, that I need to let them see their notes and everything clearly. I tend to keep the lights on."		I
	"I really don't have a problem about how the lights are laid out."		I
	"The one thing about the light that can be nice is if I have dual light controls, if I can kill these front setup lights without affecting the back lights."		I

N2-1S **G2**

Figure 4-4 Example of participant-by-space data matrix

4.5.2 Classification of Participants

Participants are classified according to teaching models they have adopted. Three models from the pedagogical spectrum are considered for further analysis. In a top-to-bottom order these models are (1) the direct instruction models (teacher-centered), (2) direct-to-social models, and (3) the social models. The social-to radical and the radical (student centered) models are discarded due to reasons explained in the following sections.

This classification is supported by definitions from the literature of different pedagogical approaches, as well as data gathered. Table 4-2 and Figure 4-5 describe distribution of the research sample.

Table 4-2 Classification of participants according to teaching model

Participant	**Discipline**	**Teaching Models**				
		Direct Models	**Direct to Social Models**	**Social Models**	**Social to Radical Models**	**Radical Models**
Teacher (1)	Computer Science				x	
Teacher (2)	Mathematics	x				
Teacher (3)	Anatomy/Microbiology			x		
Teacher (4)	Chemistry/Physics		x			
Teacher (5)	Mathematics		x			
Teacher (6)	Physics			x		
Teacher (7)	Research/Anatomy		x			
Teacher (8)	Mathematics	x				
Teacher (9)	Mathematics		x			
Teacher (10)	Aviation & Aerospace		x			
Teacher (11)	Aviation & Aerospace		x			
Teacher (12)	Health & Human Services				x	
Teacher (13)	Science		x			
Teacher (14)	Engineering & Architectural Design		x			
Teacher (15)	Environmental Sciences		x			
Teacher (16)	Chemistry	x				
Teacher (17)	Mathematics	x				
Teacher (18)	Biology & Biotechnology		x			
Teacher (19)	Chemistry		x			
Teacher (20)	Mathematics	x				
Teacher (21)	Mathematics		x			
Teacher (22)	Mathematics	x				
Teacher (23)	Mathematics	x				
Teacher (24)	Computer Sciences	x				
Teacher (25)	Physics & Computer Applications		x			

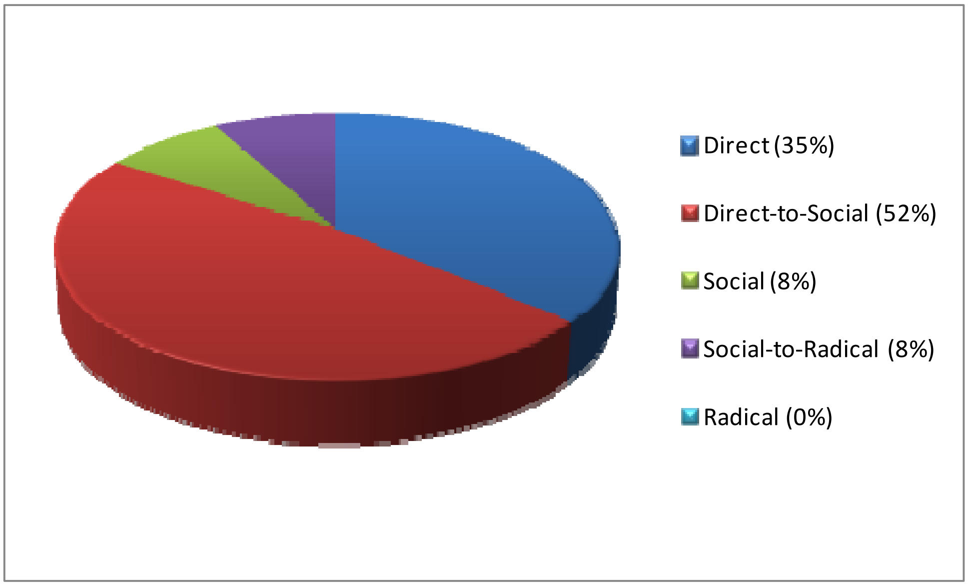


Figure 4-5 Distribution of research sample according to teaching model

4.5.2.1 <u>The direct model</u>

In the research sample, nine teachers (35%) represent the direct model. They indicate that their students are mostly recipients of information with minimum individualized contribution in the teaching-learning process. While only one teacher describes herself as a "Presenter" of course content, all other seven consider themselves "Instructors" in response to the initial web-survey, and they also define their primary role in the teaching-learning process as "to help students acquire subject matter."

Although most Direct-Model teachers point out the importance of the group as a learning medium in the web-survey, group work comes second during their typical classes as they indicated during the interviews. Teacher (2) describes teaching-learning activities taking place during his typical mathematics class saying: *"I don't do group work as much as I should… what I basically do is individual work and me teaching… I guess my teaching style tends a little bit more towards lecture style."*

The term "lecture style" is repetitively mentioned during interviews with this group of participants, whether directly or indirectly while describing their learning environments, technologies they use or furniture they prefer in their rooms. Teacher (17) states that: *"I'd like to have a podium… they don't do a lot of that here because they want to kind of keep the teacher more connected with the students. A podium tends to do just* *the opposite. So…but I like a podium because it kind of gives me a focal point from which to lecture from."*

Also, teacher (24) describes his preference of the tiered layout of a classroom saying: *"What I would like, ideally, and it would involve a complete redesign of the room...is something like an amphitheater… and the idea is that the screen would be here, and the teacher would be here on a lower level. You have to sort of envision this as a three-dimensional space. And the teacher could be over here to the side perhaps. And then the students would sit in circular rows that would be built up in tiers*." (Figure 4-6) This layout typically limits physical access between students and teacher and consequently minimizes their contribution in the process to visual and oral communication, and most of the time it restricts the teacher to the lecturing position.

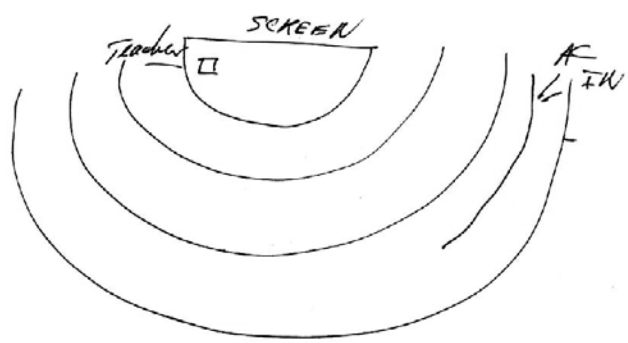


Figure 4-6 Tiered seating configuration- illustration by teacher (24)

Teacher (16) describes learning-technologies she uses reflecting on her direct-instruction approach saying: *"I do a lot of lecturing using PowerPoint because there's a lot of information they have to get in the year. So normally, when a typical class starts off, I do a lecture with PowerPoint, they copy down the notes. And the second thing I do is a lot of labs. So they get the content with the PowerPoint and then I do labs to kind of reinforce concepts"*.

4.5.2.2 The direct-to-social model

Moving towards more social teaching, the second group of participants represents the direct-to-social teaching model. As previously explained in Chapter Three, the most significant learning approaches in this model are case-based learning which is a flexible model leading students towards a moral or a process he or she deems “correct”. The second approach is guided design which reflects direct instruction by requiring students to read or work on pre-specified content segments or problems.

Most of the research sample, twelve teachers (52%), represents the direct-to-social model. This group of teachers encourages further students’ engagement in the teaching learning process. Teachers in this group engage group work in addition to direct instruction, and during their interviews they reflected one or more teaching-learning modes of either case-based learning or guided design as described above.

In the initial web-based survey, most teachers in this group describe themselves as “facilitators” which emphasizes the importance of the students’ role in making meaning of subject matter. Teacher (4) further explains his role as *“helping the individual student perceive concepts by actually experiencing them.”* While teacher (13) says *“I would say I am more of a guide.”*

Teacher (9) emphasizes the importance of both direct instruction and group work saying *“I provide direct instruction, as well as facilitating the learning of concepts through activities/labs that help them discover ideas through hands on experiences which are usually done in small groups.”* He also states that *“We’re kind of very between a lecture mode and activity; where we’re more collecting data and learning how to analyze the data and doing lab type of things.”* Teacher (21) describes a typical class saying *“typically what I’ll do is I’ll do some stuff on the board, and then I’ll either give them a problem or I’ll give them some group work, and then I circulate around. Or I’ll sit at the front and say, ‘You come to me with questions,’ and we’ll work through…Fairly traditional”*. This preference is also represented in most teachers’ graphic presentations of their classrooms.

Figure 4-7 and Figure 4-8 illustrate classroom spaces by teachers (7) and (10) where a project area is created next to a lecture space.

Figure 4-7 A two-zone space- Illustration by Teacher (7)

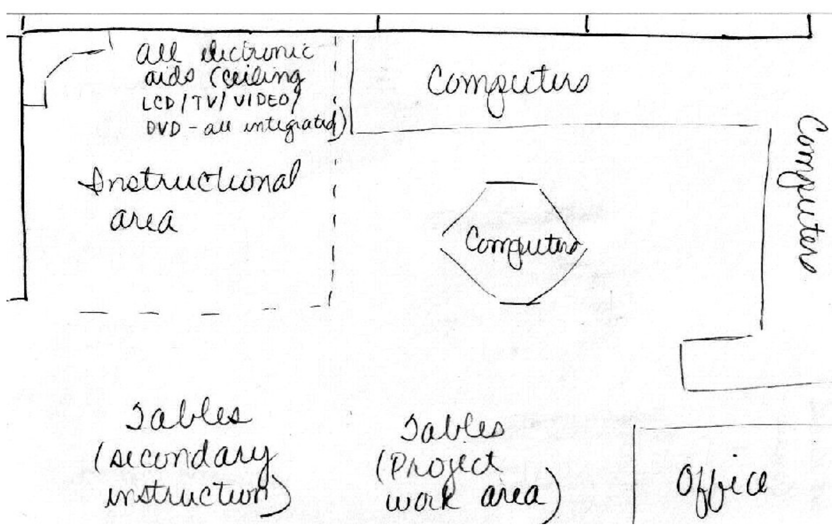


Figure 4-8 A two-zone space- Illustration by Teacher (10)

While teacher (9) manipulates the classroom to host both activities by selective decisions for individual desks which can be reconfigured to accommodate different activities in the space as he illustrates in Figure 4-9

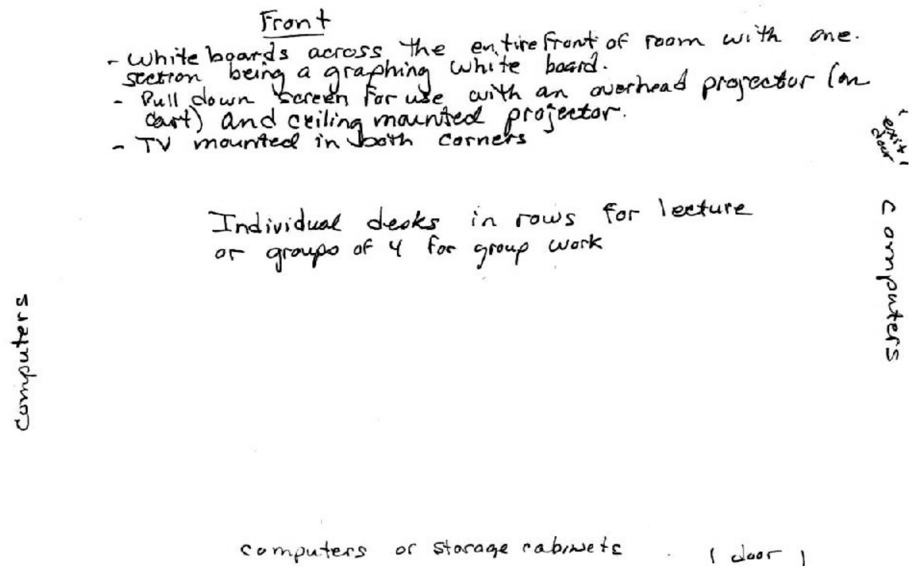


Figure 4-9 Selective choice of flexible seating configuration -Illustration by Teacher (9)

Another common approach among this group of teachers is providing students with real-world experiences through learning activities which corresponds to their case-based teaching scenarios. Teacher (13) emphasizes the importance of this approach saying *"I think that in a place like this it's great to be able to have up to date information on weather channels and things like that available. So I think that being connected to the world is really important nowadays. Kids need to see outside themselves and see how other things are happening."* While teacher (15) describes activities in his class saying *"The activities in my class are models of real world situations, hoping the students make a connection between the two and is better prepared to make those 'real world' decisions based on what went in the classroom."*

This approach is also reflected in teachers' spatial preferences. Teacher (14) elaborates on this concept saying "*it doesn't bother me a bit to see them look out the window…I like for them to look around and be aware and that's another thing we try to teach here, be aware of your surroundings and the children this age are."*

4.5.2.3 The social model

The last teaching model considered for analysis in this study is the Social Model. This model generally relies on students' self apprehension in the learning process, and is represented in anchored instruction, cognitive apprenticeships and cooperative learning. All approaches invite students to work on projects or problems in teams with both personal and team accountability for conceptual understanding with close scaffolding by the instructor.

Only two participating teachers (8%) adopt this model in their teaching practice within the research sample. Both apply a significant amount of laboratory work and experimentation as teaching-learning activities. Both teachers did not provide information through the web-based surveys, therefore all data regarding this model was primarily gathered during the classroom visits.

Classroom layouts they illustrate reflect the need for group communication as represented in Figure 4-10 and Figure 4-11 .

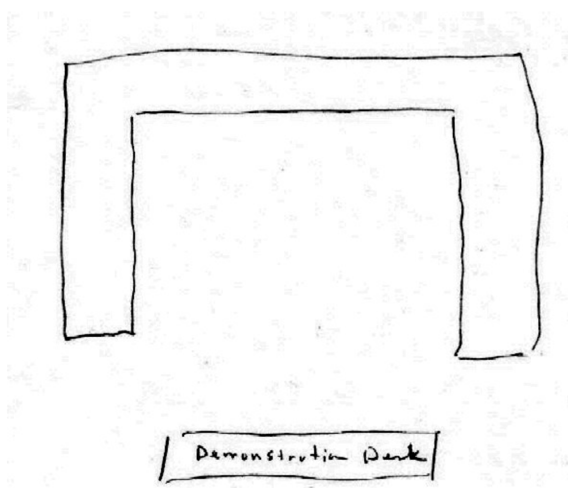


Figure 4-10 U-shaped configuration for group communication- Illustration by Teacher (3)

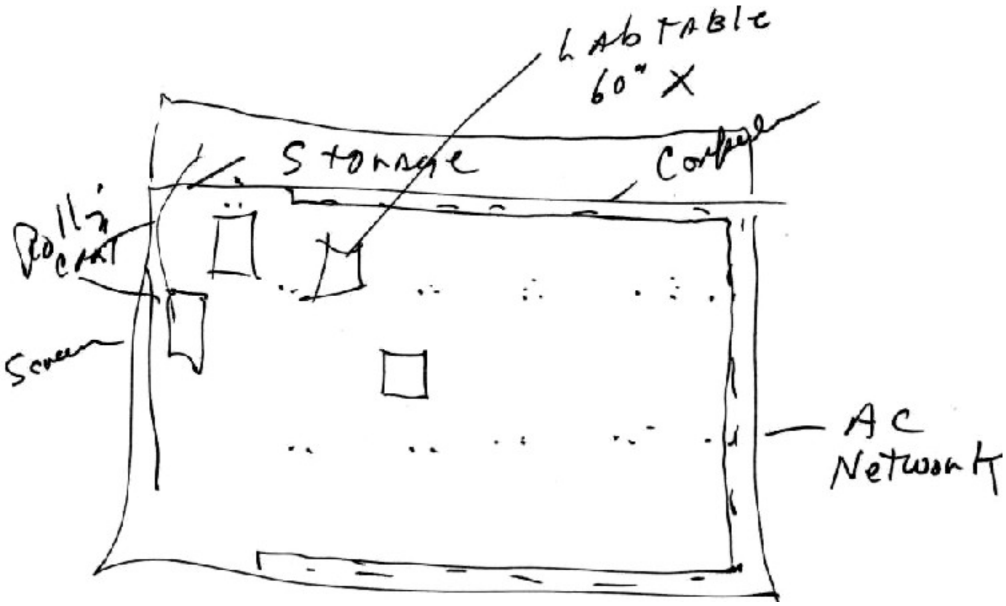


Figure 4-11 Reconfigurable tables to accommodate different sizes of students groups-Illustration by Teacher (6)

4.5.2.4 <u>The social-to-radical and radical (student centered) models</u>

While none of the participants adopt the radical (student-centered) model of teaching, two participating teachers (8%) represent the social-to-radical model. Data gathered for this group will not be considered for further analysis for two reasons:

- Coding results for data gathered from teacher (12) could not be grouped with other results due to the different nature of the discipline she teaches, that is Health and Human Services.
- For teacher (1) who is the only other participant representing this pedagogical model, the data he provides in graphical illustration does not support the information provided by other data gathering modes.

As data is gathered and organized from each group of teachers described above, data analysis concludes a set of design patterns for each group and can be utilized for the early design phases of learning environments as will be described in the following sections.

CHAPTER 5 PATTERNS OF TECHNOLOGY INTEGRATION

Through two iterations of coding, three groups of patterns emerge from data collected from teachers in the three pedagogical models (direct, direct-to-social, and social). Although only the first set of patterns meets the goals of this research, all three sets are briefly discussed in this introduction. These patterns are:

- Patterns of Technology Integration, which is the focus of this dissertation and is further analyzed and discussed in the following sections of this chapter. These are design patterns for integrating learning technologies with other systems in the learning environment, and they reflect teachers' modes and patterns of using different learning technologies in the teaching-learning process. Four major themes are discussed in the coming analysis sections; these are (a) Accessibility and communication, (b) Mobility, (c) Position and location of technologies, and (d) Modes of use.
- Patterns of the Physical Space, these are design patterns for the physical environment and integration of the architectural systems within it. Four major themes emerge; these are (a) Space layout and orientation, (b) Controlled space conditions, (c) Response to activity patterns, (d) Systems and occupants within the space. Appendix E presents code mapping for this set. Analytical discussion of this set of patterns is beyond the goals of this dissertation but is considered for future continuance. Yet, frequent reference to patterns of the physical space is obvious throughout this analysis chapter.
- Patterns of Space Occupancy, these are primarily derived from patterns of events occurring by occupants of the space, particularly activities within it and modes of use, for example issues concerning variations in teaching instances, modes and activities, individual preferences, teaching traditions and habits, tools and methods of future retrieval of information as well as interactions between students and teacher and among students. These patterns also lie beyond the scope of this study and need further investigation in collaboration with experts in education-related fields.

The following sections discuss Patterns of Technology Integration which vary in priority according to the teaching model. Table 5-1 summarizes the codes and themes emerging through the first and second iterations.

Table 5-1 Code mapping for patterns of technology integration

<table>
<tr><th colspan="3">Second Iteration of Coding (Emerging Themes)</th></tr>
<tr><td colspan="3">Accessibility and communication
Mobility
Position and location of technologies
Modes of use</td></tr>
<tr><th colspan="3">First Iteration of Coding (Initial Open Codes)</th></tr>
<tr><th>The Direct Model</th><th>The Direct-to-Social Model</th><th>The Social Model</th></tr>
<tr><td colspan="3">- Connection between technologies</td></tr>
<tr><td colspan="3">- Remote/ wireless mobility</td></tr>
<tr><td colspan="3">- Controlled lighting conditions</td></tr>
<tr><td colspan="2">- Visual access to technologies</td><td></td></tr>
<tr><td colspan="2">- Area of instructional wall (multi-layer wall)</td><td></td></tr>
<tr><td colspan="2">- Mobile control of fixed technologies</td><td></td></tr>
<tr><td colspan="2">- Distance and height of technology</td><td></td></tr>
<tr><td colspan="2">- Physical access to fixed technologies</td><td></td></tr>
<tr><td colspan="2">- Access locations/portals</td><td></td></tr>
<tr><td>- Access Restriction for safety and maintenance</td><td></td><td>- Access Restriction for safety and maintenance</td></tr>
<tr><td>- Multi-use technologies</td><td></td><td>- Multi-use technologies</td></tr>
<tr><td></td><td>- Monitoring</td><td></td></tr>
<tr><td></td><td>- Availability of space and designated locations for technologies</td><td></td></tr>
<tr><td></td><td>- Visual communication between students and instructor</td><td></td></tr>
<tr><td></td><td>- Remote communication between students and instructor</td><td></td></tr>
<tr><td></td><td></td><td>- Permanent Display</td></tr>
</table>

As described in chapter 2, pattern formulation is initialized in a context, which is represented in the teaching models adopted in the learning environments. This context creates systems of forces primarily driven by patterns of events, and they are represented in the form of design criteria and constraints. Finally, a configuration emerges which represents the recommended patterns of space. In description of pattern formulation throughout this section, tables represent this process as first introduced by Alexander.

Also, as discussed in chapter 2, systems' integration can take place at any of the following five levels: the remote; where systems do not physically touch, the touching; where they contact without a permanent connection between the systems, the connected; where they get permanently attached, the meshed, when they interpenetrate and occupy the same space, and the unified; where they are not distinct (Rush, 1986, pp.13-14). Within this analysis section, integration between learning technologies and the components of the interior and envelope systems is described and measured on this scale of levels.

Themes emerging from code mapping for this category are:

5.1 Theme One-Accessibility and Communication

This theme describes design patterns for enabling or restricting accessibility to some learning technologies whether visually, physically or even remotely. This is typically preferred for safety issues, to minimize distraction, allow for more convenience or higher comfort levels when these technologies are in use. Table 5-2 represents patterns emerging under this theme.

Table 5-2 Patterns Emerging under Theme One-Accessibility and Communication

Theme One **Accessibility and Communication**
1. Access Restriction for Safety and Maintenance
2. Physical Access to Fixed Technologies
3. Visual Access to Technologies
4. Access Locations/Portals
5. Remote Communication between Students and Instructor
6. Visual Communication between Students and Instructor

5.1.1 Access restriction for safety and maintenance

This pattern emerges from data gathered from teachers of the direct and the social models of teaching. It reflects teachers' concerns regarding performance of learning technologies if they are exposed to occupants' circulation and movement. This pattern questions integrating learning technologies with the envelope of the space (floor, ceiling and walls) as well as the interior system. Issues like wiring, mounting and placement of learning technologies whether in a fixed location or on a mobile piece of furniture start to emerge.

Mostly, teachers express their preference for integrating projection devices in the ceiling plane in order to secure the alignment of the projection board, as well as safe circulation for occupants. Teacher (23) explains the advantages of having a ceiling-mount projector saying *"It is a plus, instead of having the projector on a roll-around cart—so that it keeps getting bumped all the time, especially if you're working with a smart board. You have to re-register your smart board every class, or in the middle of class. It's a real pain"*. Teacher (19) supports the same idea saying *"finally we got this … ceiling –mount projector, this was done last year after school was out, which was wonderful because it used to sit on that cart…Well, anytime anybody would go by, even though I had the wheels locked, and bump it. And it's out of alignment with the smart board. So I was always having to reorient the smart board. Plus the cart here was in the way. It's sitting by here so the chairs were back there."*

In Figure 5-1, teacher (2) captures an image of his projector placed on a mobile cart with connected integration to the wall plane which introduces wiring in the space and decreases the safety factor in this area of projection. He comments on this situation saying *"The projector should actually hang from the ceiling, taking it out from the way"*.

Other integration criteria that emerge are spatial as well as visual. Teacher (17) favors his TV mounted at the corner of the room for the reason he explains saying *"that's the best accommodation that I've seen as far as the TV setup is concerned. I've had situations where you've had to wheel the thing in on a cart and was in a room twice as long as this and in the back the students can't even…hopeless to see,"* as Figure 5-2 illustrates. Teacher (20) explains her desire to eliminate the projector cart from her classroom due to spatial and visual integration reasons saying *"Because the classroom is so big, I feel like I want to* *utilize that space and so I'd like to have the projector far enough out where it's not blocking anything. But I can't focus it well enough because of the location. So I have to constantly move it back and forth. It would be nice to have a permanent—something like that mounted or maybe something with a little more high tech than an overhead projector".*

Figure 5-1 A projector cart- Image captured by Teacher (2)

Figure 5-2 Mounted TV screen for better visual access- Image captured by Teacher (17)

In some of the investigated learning environments, there is the opportunity of integrating learning technologies with the floor. Teacher (22) expresses concerns regarding this kind of integration when it comes to classroom maintenance saying *"When they sweep the floor the connections sometimes are broken."*

This pattern highlights issues concerned with integrating learning technologies with the envelope and interior systems at different integration levels. The major performance mandates discussed are visual, spatial, safety as well as aesthetics. Table 5-3 summarizes the pattern formulation. The pattern Access Restriction for Safety and Maintenance is also illustrated in Figure 5-3.

Table 5-3 Access Restriction for Safety and Maintenance- Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
-Direct - Social	-Technology alignment -Occupants' safety -Visual access to technologies -Spatial orientation of technologies	-Integrate learning technologies with ceiling or wall planes (at connected or touching levels) -locate learning technologies eliminating the potential for visual obstruction - Design for easy maintenance when integrating with the floor

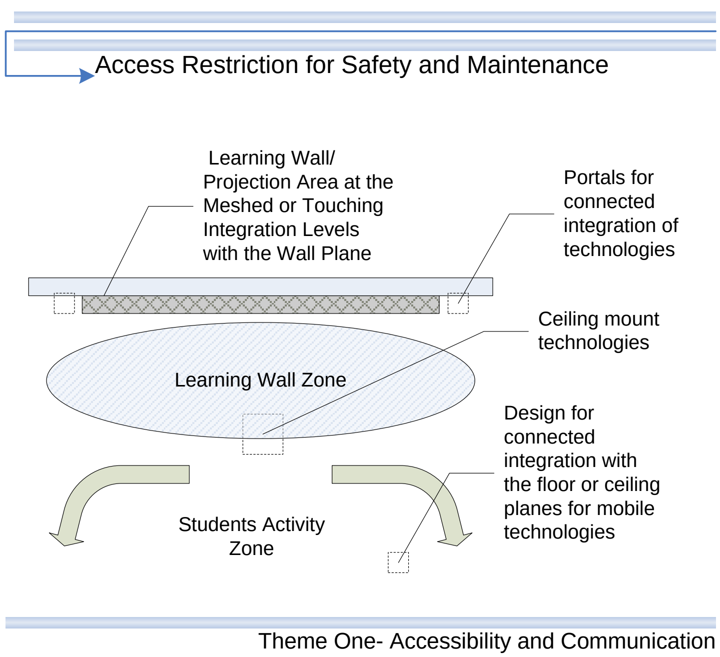


Figure 5-3 Access Restriction for Safety and Maintenance

5.1.2 Physical access to fixed technologies

This pattern emerges in the direct and direct-to-social teaching models and discusses integration of learning technologies within the space while questioning spatial, safety and aesthetic performances by pointing out issues like access, location of learning technologies, ergonomics, as well as integration levels.

When considering integration of learning technologies with the circulation component of the interior system, it is critical that teachers and students, when desired, be able to physically access learning technologies with least obstruction, directly and safely. In Figure 5-4 teacher (17) captures the computers located in the rear end of his classroom, which enables easy and direct access for students coming into the room. He explains this situation saying *"this room is used also as a research…as a student research room and it's allowed students to have pretty easy access to the computers up front"*.

Figure 5-4 Direct access to computers in the room- Image captured by Teacher (17)

When learning technologies are integrated at the connected level, wiring is an issue inside the space and accessibility can be an issue. Also, decisions concerning the location and level at which these technologies are integrated should be informed by human ergonomics and physical performance to ensure direct and safe access, for example space for handicap access, height of user, and location of user in relation to the technology and other viewers should be considered. Teacher (20) highlights ergonomics-related issues saying *"My computer location with the hub for the smart board is not working. Because*

I'm right handed, I need to be here. And when I'm here trying to point things out, I'm covering up and I'm running into my students," as she captures in Figure 5-5.

Figure 5-5 Position of smart-board related to teacher's access- Image captured by Teacher (20)

Pattern formulation is summarized in Table 5-4 and Figure 5-6 for the pattern Physical Access to Fixed Technologies.

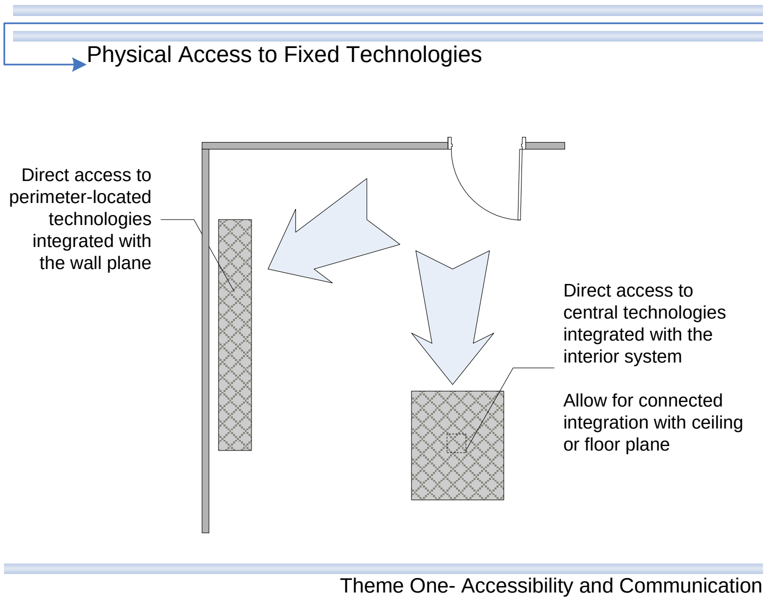


Figure 5-6 Physical Access to Fixed Technologies

Table 5-4 Physical Access to Fixed Technologies- Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
-Direct - Social	- Direct and safe access for teacher and students to fixed technologies - Ergonomics-related design criteria	-When desired, design for immediate and easy access for students to learning technologies without interrupting class activities -Consider ergonomics when mounting fixed learning technologies (height, location, direction relative to people and furniture ...Etc.)

5.1.3 Visual access to technologies

As opposed to the previous pattern, this pattern is concerned with visual access to learning technologies rather than direct physical access. It also discusses the need for direct visual access between teacher and students in most teaching-learning situations in the learning environment. This pattern also emerges in both the direct and direct-to-social models of teaching.

Teacher (24) highlights the importance of providing direct visual access to learning technologies whether students work individually or in groups saying *"mainly what my classes are about is projected on a projector. The students follow along on their computers, but of course it's very important that they able to see what I'm doing"*.

Visual obstacles can be easily created in a classroom environment, and this can be overcome by selective decisions regarding the height and the angle at which these technologies are integrated with the envelope planes. Teacher (20) discusses the situation with her TV screen saying *"I hate that TV there. I hate it there. It needs to be in the corner or it needs to be in this corner or that corner. It needs to be out of the way. It needs to not be in the front of the room. That is awful,"* as she also captures in Figure 5-7

Figure 5-7 The TV screen as a visual obstacle in the room- Image captured by Teacher (20)

A similar situation is expressed by teacher (5) who mentions *"They have a horrible time if they are sitting on this side… because of the TV. When they put up the TV there was no place to put it, they couldn't block the closets on the right or the door on the left, they only could put it over here, which blocks the board,"* as she captures in Figure 5-8.

Figure 5-8 The TV screen as a visual obstacle in the room- Image captured by Teacher (5)

Teacher (16) describes a situation which emerges for large or multi-task learning environments, which is the need for multiple visual focal points in the room. She describes having three TV screens in her chemistry lab, and consequently three visual focus points saying *“the kids in the back will look at that TV and the kids in the front look at this TV [pointing]… This one [the third monitor] is on the microscope”*. This situation calls for multiple integration points with the interior and envelope systems.

Figure 5-9 and Table 5-5 summarize the pattern formulation.

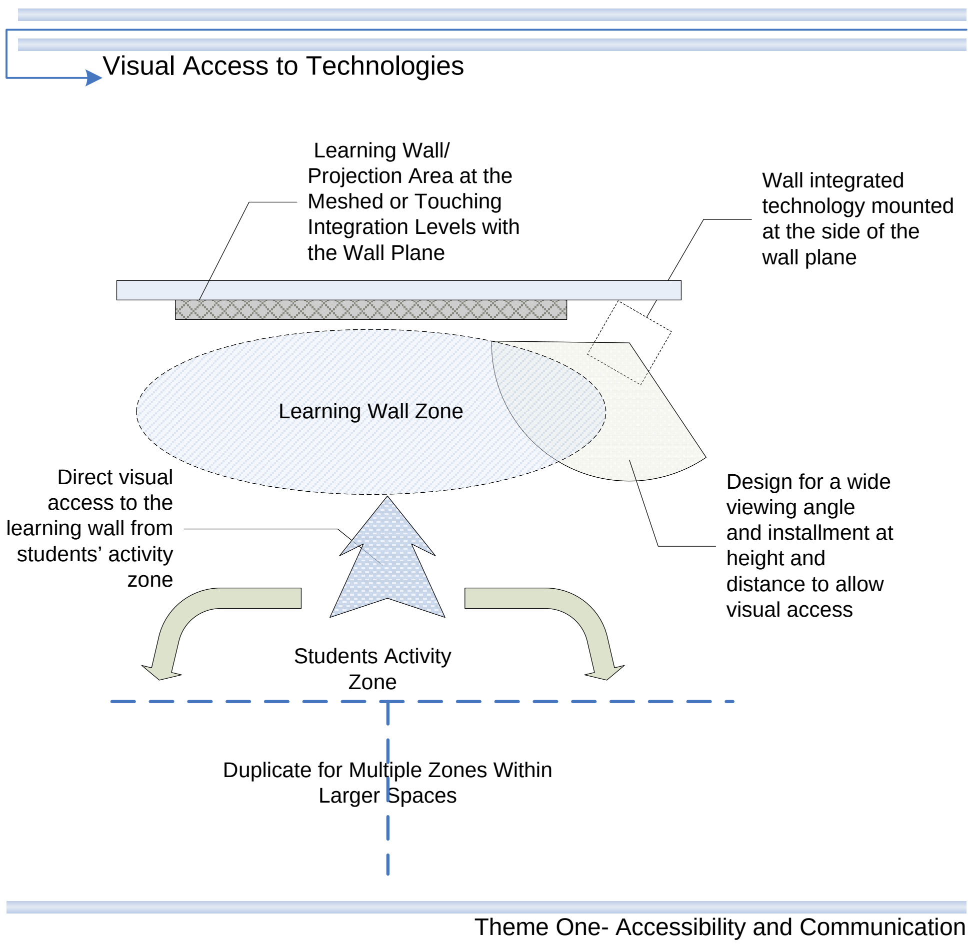


Figure 5-9 Visual Access to Fixed Technologies

Table 5-5 Visual Access to Technologies-Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
-Direct - Social	-Need for direct visual contact between students and teacher -Visual obstacles can be created in the room with learning-technologies - In large, multi-task rooms, multiple visual focal points are needed.	-Allow for a clear direct visual path between each student and anticipated teacher's location(s) in the room -Locate clear visual paths to learning technologies, while eliminating obstacles within this path. - In large, multi-task rooms, design for visual focus zones to accommodate larger number of students, multiple work zones or multiple activities.

5.1.4 Access locations/portals

In a technology-rich learning environment, with significant opportunity to host multiple teaching-learning activities, it is important to provide a proper strategy of laying out the electricity and services portals. This pattern also emerges in the direct and direct-to-social models of teaching.

Teacher (19) whose work takes place in a chemistry lab suggests that there is *"never enough outlets,"* and explains that *"even though we have many electrical outlets, there are still not enough. That's why I have all these strips,"* which she adds at the perimeters of her laboratory to provide extra electric outlets. Also, teacher (25) who works in a physics lab similarly states that *"practically speaking, I would have thought that I had plenty of electrical outlets. I need more".*

The discussion of integrated design for this pattern questions integration with the envelope planes and number of points at which this integration occurs. This integration opportunity influences spatial performance within the space where furniture, equipment and occupants are bound with locations of these points in order to ensure access to electricity and services, whether these points are provided from the wall, floor, or ceiling planes. A frequently observed example is the location of computer stations along the perimeters of the space to be accessible to electricity access points.

Also, there is the potential for integrating some learning technologies like desk-tops and lap-tops to the furniture system which enable access to electric outlets and other service portals.

Aesthetic performance of the space is critical when integrating learning technologies to access electricity portals whether they are wall, floor, or ceiling integrated. Teacher (21) elaborates on the aesthetics and ergonomics issues of the problem saying *"the wiring is not very good. There are not enough plugs. There are too many wires hanging. I think it's an eyesore—and particularly because [the TV] does not swivel, I think it's pretty much useless. I'm lucky because I'm short, but if I get someone taller in here, it's right up there in their head,"* as Figure 5-10 illustrates. Table 5-6 represents pattern formulation.

Figure 5-10 Wires hanging from TV set-Image captured by Teacher (21)

Table 5-6 Access Locations/Portals- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
-Direct - Social	Need for enough accessible electric outlets in the space. -Physical presence of wiring (safety/aesthetics)	- Design for safe and accessible locations for electricity outlets. -Depending on activity patterns, chose accessible locations: wall, ceiling or floor integrated (perimeters versus center of the room)

5.1.5 Remote communication between students and instructor

This pattern emerges in the direct-to-social model. The pattern offers an argument and a potential for more flexibility in designing learning environments. It specifically points out the possibility for teachers and students to communicate remotely within the space eliminating the need for the designated location for teacher's station and offering a larger variety in the layout of learning environments, where teachers can monitor and communicate with their students without the need for direct physical or visual access in many cases.

Teacher (25) suggests a different application for graphic tablets to provide mobility while efficiently communicating with students saying *"There's this device that is a graphics tablet… I like that concept. The fact that you could have 2 or 3 of them in the room and you could hand it to a student and they could write things and have it projected, as opposed to using the whiteboard and everything like that. It would help if it has a screen so that there would be feedback…So, I think that technology has got some potential that I think might be worth taking advantage of being able to walk around the room and annotate".*

The application of this pattern challenges integration levels and locations with the envelope planes and the furniture system. It also influences spatial performance with the space as described above as well as acoustical and visual performance. Table 5-7 summarizes pattern formulation.

Table 5-7 Remote Communication between Students and Instructor- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
Direct-to-Social	- Teacher and students can be freely moving while remotely using learning technologies for communication. - High potential for altered space layout and room configuration.	- Limit design for designated instructor and students locations, unless desired.

5.1.6 Visual communication between students and instructor

A pattern associated with visual communication primarily emerges in the direct-to-social teaching model, where teachers express the importance of eye contact with students to promote visual communication between them.

Teacher (18) mentions that *"In a typical class we're using the…almost exclusively now, the projector with the computer…Either using PowerPoint or writing on the screen. I find that if I'm writing on the screen I'm watching the kids at the same time or talking with them. If you're writing on the board you turn your back to them."* Teacher (25) expresses a similar idea; he prefers to be directed towards his students rather than working on a board. He says *"I don't like the smart board…. I find that there are some things I could do on the screen so I'm facing the kids more directly, rather than my back to them and looking up here"*.

Teacher (19) prefers physical presence between the students rather than being tied to a front board. She says *"I'm always walking around the room, and come back up here and the board… I like open between me and the students… That way, when you're walking around you can see what they're doing—make sure they're paying attention to you, not playing a game on their cell phone now or on their calculators, or doing other homework"*.

Thus, integrating learning technologies with the circulation component of the interior system is critical in the application of this pattern in order to provide for this kind of visual access between students and teacher.

Table 5-8 summarizes pattern formulation for visual communication between students and teacher.

Table 5-8 Visual Communication between Students and Teacher- Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
-Direct - Social	-Need for direct visual contact between students and teacher. -Visual obstacles can be created in the room with learning-technologies - In large, multi-task rooms, multiple visual focal points are needed.	-Allow for a clear direct visual path between each student and anticipated teacher's location(s) in the room - In large, multi-task rooms, design for visual focus zones to accommodate larger number of students, multiple work zones or multiple activities.

5.2 Theme Two- Mobility

This theme reflects teachers' and students' desire to be able to move freely during teaching-learning activities. With the availability of contemporary learning technologies, there is a strong potential to establish such mobility due to the availability of wireless communication. Specific patterns are as listed in Table 5-9.

Table 5-9 Patterns Emerging under Theme Two- Mobility

Theme Two Mobility
1. Remote/ Wireless Mobility
2. Mobile Control of Fixed Technologies
3. Remote Communication between Students and Instructor

5.2.1 Remote/ wireless mobility

This pattern emerges in interviews with teachers in the three teaching groups. It emphasizes the role which wireless technology plays in providing more freedom and mobility for students and teachers during teaching-learning activities.

The availability of wireless communication highly influences spatial performance of learning environments. It offers a huge potential for more flexible layout and the freedom to move across the space without being wired to specific locations to access electricity or internet services.

Most teachers mention that they are moving more towards using laptop computers rather than the older desktop computers due to the availability of this wireless technology. Obviously, the furniture system is also altered to accommodate this kind of wireless communication and smaller-sized laptops, desk-top perimeter stations can also be replaced with more mobile furniture units to allow for free flow inside the space.

Teacher (24) describes this situation saying *"I think more and more we'll be going to laptop computers, something like this. And the space situation will be improved because even if we don't have the amphitheater-type arrangement, because instead of having all this equipment you'll just have this much space for your computer. I hope that happens…And then people can kind of sit where they want to sit. It's less regimented where you have to pull up a seat in front of where a computer is"*. Teacher (18) agrees on this trend saying *"I think we're going to end up replacing all the desktops with laptops eventually and then use the wireless"*. Teacher (25) also states that *"I really think laptops are probably the way to go… I think I would say we don't want to plan for desktops nearly as much as the flexibility of laptops. Wireless laptops, and then go on the desks, or be used as the lab station. And then the question is does each individual kid have their own laptop or do you have laptops that are placed in a storage area and then they go pick them up and bring them to the lab station or bring them to the desk and use them"*.

Also integration with the circulation component of the interior system is significantly influenced. Teacher (10) describes one benefit of using a laptop computer in regards to mobility saying *"The laptop fits in that cart, so it's quite mobile, so we can put it in either place where we want it."* Teacher (15) further elaborates on wireless opportunities with learning technologies saying *"I would love a ceiling mount screen… That way if I had that … I could use my laptop from anywhere, you know. I guess they have wireless hookups to an LCD"*. Teacher (1) describes another opportunity for teachers saying *"If we had wireless capability, the teacher can choose ... because they have the capability to choose which monitor can be flashed on the smart board"*.

On the other side, students are also able to move freely in the classroom or laboratory because of this technology. Teacher (16) describes students' ability to monitor their experiments at their chemistry lab benches saying *"we have wireless in this room so they can have computers at their lab benches and connect it to different probes and sensors."* Teacher (18) expresses the same opportunity for students saying *"I do bring* *laptops in here sometimes so they can just sit at these tables and work with their laptops"*.

Table *5-10* describes formulation of this pattern.

Table 5-10 Wireless Mobility- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
-Direct -Direct-to-Social - Social	- Mobility of teacher's computer and computer station - Remote communication between teachers' computer and other learning technologies in the room -Students mobility between desks, lab tables and their computers -Locations, storage and space for computer stations	- Allow for wireless-enabled devices and learning technologies -Allow for multiple surfaces and locations to act as the teacher's laptop station. Can be a mobile surface when desired. - If desired, replace permanent computer stations for students with smaller mobile furniture. - When needed, designate locations for storing students' laptop computers.

5.2.2 Mobile control of fixed technologies

One of the most frequently emerging patterns among teachers of the direct and direct-to-social teaching models is mobile control of fixed technologies. Teachers again express their desire to communicate with learning technologies at hand from any location in the learning environment, even if this technology is at a fixed position in the room. Also, most teachers discuss their negative experiences when they had to be tied to the room front to be able to control and use learning technologies.

Teacher (16) discusses her desire to be able to control the PowerPoint slides from across the room saying *"the one thing that I would like to have… is a remote to advance PowerPoint slides and then I can walk all around the classroom and…but since it's broken I kind of feel like I'm tied to the computer. So sometimes I feel like it's hard to interact with the students in the back when you're tied to the computer in the front"*.

Teacher (20) rejects being tied to the room front due to connections between her computer and smart board saying *"I have to use an extension cord, which is running from there over to there. And so it's like I'm tied. I'm tied to right there and I can't move either way because someone will trip over that invariably, and that's not working. So* *what needs to happen is that they just need to activate [electricity outlets]…make sure that ALL of these are activated or they need to be in the wall"*. Figure 5-11 captures the situation she describes above.

Figure 5-11 Wiring restricts teacher mobility- Image captured by Teacher (20)

This is another pattern that questions spatial performance of learning environments due to the flexibility it offers, or does not offer, in the space layout. It also limits opportunities for integrating learning technologies with the circulation component of the interior system whether for occupants' movement in the space or circulation of learning technologies. Teacher (15) moves learning technologies such as boards to different locations in the room for instructional purposes. He describes his purposes saying *"I'll move [the white board] around, sometimes I'll write instructions on here and then take that whiteboard over to the computer so that…. So we don't have to keep running back and forth"*.

Teacher (21) also prefers moving some of the learning technologies around the room. She illustrates that in Figure 5-12 and further explains saying *"I've got my smart board here. I actually don't use it as much as I probably should. But it is really nice to have. You have to pull the computer out. I actually prefer that because then I can move the computer around, I can project wherever I want. A lot of the rooms have the projector mounted up in the ceiling. I actually… I wouldn't mind it, but I like having it so that I can turn it around and project wherever I want…Or I can project on the screen or wherever. If it's fixed it just has to point right at the smart board. I don't feel like I use it* *enough to warrant paying to have it mounted. I can pull it out and use it when I need it…I use the board most often".*

Figure 5-12 Mobile computer cart- Image captured by Teacher (21)

Figure 5-13 and Table 5-11 illustrate pattern formulation.

Table 5-11 Mobile Control of Fixed Technologies- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
-Direct -Direct-to-Social	-Teachers need to communicate with their students while using learning technologies. - Placement and connections of learning technologies restrict easy and safe teacher's movement from their locations. - Some learning technologies need to be mobile around the room.	- Promote the use of remotely controlled learning technologies - Allow for teacher's safe movement, access and ergonomically designed spaces around fixed learning technologies -When desired, design for the possibility of moving learning technologies around the room.

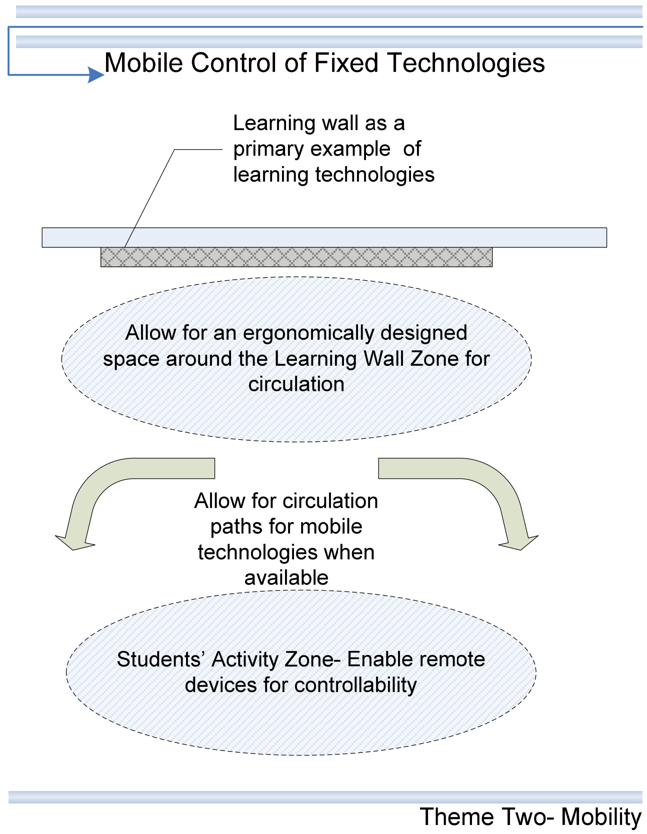


Figure 5-13 Mobile Control of Fixed Technologies

5.2.3 Remote communication between students and instructor

As described in Theme One- Accessibility and Communication, using learning technologies which enable remote communication between students and the instructor promotes a higher potential for occupants' mobility in the space. This offers new integration opportunities between learning technologies and the circulation component of the interior system, and calls for innovative room layouts and seat configurations, without the traditional need for designating specific students and instructor locations.

5.3 Theme Three- Position and Location of Learning Technologies

This theme primarily describes patterns for spatial performance when it comes to integrating learning technologies within the space. Patterns constituting this theme are illustrated in Table 5-12

Table 5-12 Patterns Emerging under Theme Three- Position and Location of Technologies

Theme Three **Position and Location of Learning Technologies**
1. Area of Instructional Wall
2. Distance and Height of Technologies
3. Availability of Space and Designated Locations for Technologies
4. Connection between Technologies
5. Controlled Lighting Conditions

5.3.1 Area of instructional wall

The instructional wall is the front plane or the side planes which integrates most of the learning technologies used for projection and presentation. This wall can be single layered or multilayered with planes which overlap horizontally or vertically. The area of these layers is the concern of this pattern which emerges in the direct and direct-to-social models.

The traditional boards are still the preference of some teachers who claim that they can always provide more space, and are much easier to erase and re-write on. Teacher (20) who is a mathematics teacher argues for that saying *"[the smart board] is not enough room; it's not enough space. And I would be capturing and saying 'Excuse me while I capture.' And then I erase everything and start over. At least these boards are long enough; I can work a whole problem. And some of these problems take a lot of steps"*. Teacher (9) who is also teaching mathematics mentions *"I don't have enough board space… A white board across the entire front of the room with one section being a graphing white board. Then a pull-down screen, and an overhead projector and a ceiling mount projector,"* as she suggests in her illustration of her learning environments (Figure 5-14).

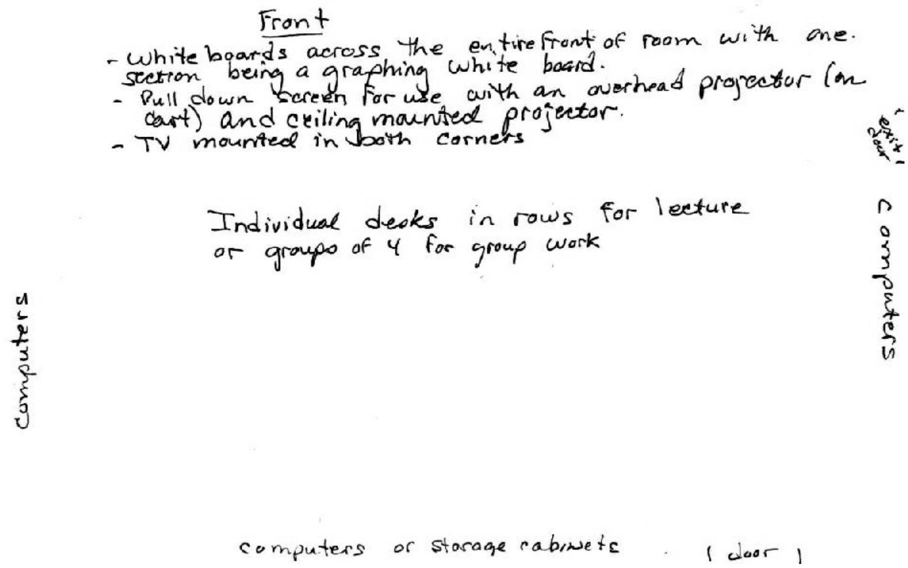


Figure 5-14 Suggestion for boards across the room front-Graphic illustration by Teacher (9)

Figure 5-15 Area of instructional wall currently available for Teacher (9)

The area and location of the instructional wall influences the visual performance in the space, where this technology should be visually accessible to all students around the space. The need for wider projection area is significant when integrating projection technologies for learning purposes. Teacher (24) argues for more projection area for better visual performance saying *"it would help me to have a bigger screen and a better projector that would project to a wider screen"*. Similarly, teacher (5) mentions that *"It is hard to see the TV if you're at the back of the room, so having a TV is not ideal, the* *ideal situation would be to have a larger screen, and have a projector to be able to project the computer onto that."*

Teacher (21) manipulates the need for projection surface by projecting over the bulletin board. She describes the situation saying *"This actually right here is a bulletin board, but I've covered it with white paper because I like to use it for my projection. My projection screen hangs right there [over the white board on the perpendicular wall], and if I pull down the screen it covers my board and I can't use both at the same time… I actually considered having it moved, but in order to have it come so that it won't cover my board, we needed to get long cords up where the ceiling does it's little larger-to-smaller ceiling."* Figure 5-16 illustrates the image she captures for this particular situation.

Figure 5-16 Using the bulletin board for projection- Image captured by Teacher (21)

Teacher (25) also manipulates his learning wall to allow for multi-activities. He describes the situation saying *"There are times when I'm projecting onto the white board. I was projecting an image so I could draw right there on the image"*.

Integration of the learning wall with the lighting component of the interior system is also critical for visual performance in the space. Teacher (21) creates her own integrated lighting system to eliminate glare on the board for better visual performance over the white board as she captures in Figure 5-17. She explains saying *"I installed the track lighting. I made a special request and I installed that because I've got dead spots on my board that even on the brightest day, it's hard to see. It looks like my board is shaded right there. And I think part of it is where that ceiling does come down. It blocks some of* *the light. But I had students that couldn't see very well, so I did those lights. It's a temporary fix; it's not great. But it does the job".*

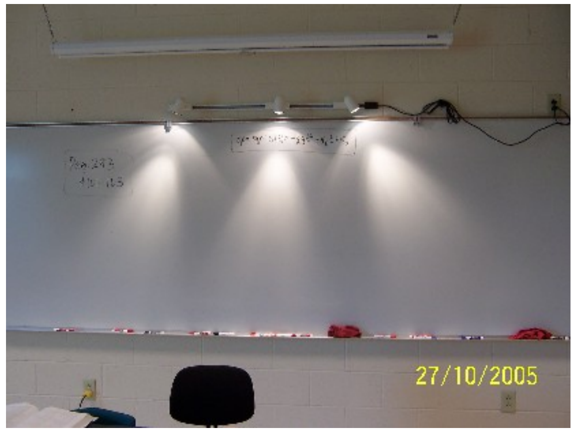


Figure 5-17 Integrated lighting system over the white board- Image captured by Teacher (21)

This pattern suggests the desire to have layers of instructional surfaces in the space. This condition suggests an interaction with the spatial performance in the space when locating these layers. The definition design for one room front or multiple room fronts is then required, and depends on teaching-learning activities occurring in the room. The furniture arrangement and visual focus of the room are accordingly influenced. Table 5-13 summarizes pattern formulation.

Table 5-13 Area of Instructional Wall- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
- Direct -Direct-to-social	- Some teachers need more instructional wall area than electronic projection can provide. - Most of the time, the small area available for electronic projection causes visual problems. - Teachers may require a multi-purpose instructional way (for example: projection and writing)	- Provide enough area for instructional wall according to teacher's requirements for his/her discipline. - Provide an area for projection which corresponds to room proportion and furniture layout. - When required, design for a multilayered instructional wall (vertically or horizontally).

5.3.2 Distance and height of technology

This pattern also emerges in the direct and direct-to-social models. It is concerned with mounting or locating different learning technologies in the space, which is critical to visual comfort and ergonomics as well as patterns of use of these technologies.

Locations of learning technologies should respond to space proportions as well as furniture layout. A number of variables are involved such as distance, height, surface qualities of the screen, angle of inclination, and most importantly ergonomics when direct interaction with these technologies is the case.

Teacher (20) questions the location of her TV screen with respect to her height saying *"I am a tall person and I am right handed, so I start on this [left]side of the board, and I hover on this [right] side a lot… and it's very irritating. The plug needs to be somewhere else so all of this isn't in my head. I don't like that. The screen is right in front of the board so if I'm teaching, I'm pulling the screen down and then I'm pulling it up. I'm pulling it down."*

She captures this situation in Figure 5-18.

Figure 5-18 Positioning of TV screen, white board, and projection screen- Image captured by Teacher (20)

Integration of these systems with the circulation component of the interior system is also an issue for both spatial and visual performance in the space. Teacher (10) describes a situation saying *"The one small disadvantage this area has is that if you want to use the* *board, the board is always away. You can have kids sitting in the back trying to look at the board back which is up there. The traffic can potentially be an issue."*

Figure 5-19 Distant between board and students' seating- Image captured by Teacher (10)

For that situation, he proposes a separate area designated for instructional purposes and integrating all learning technologies and isolated from cross circulation as he illustrates in Figure 5-20.

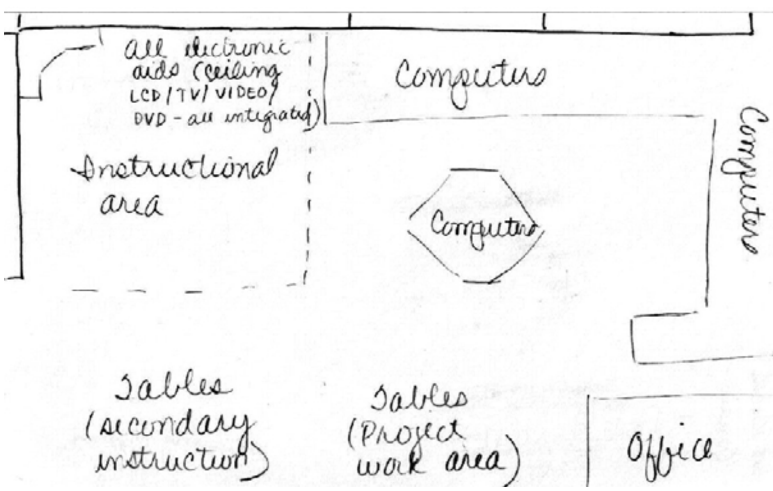


Figure 5-20 Proposal for separate instructional area with integrated learning technologies (top left) - Illustration by Teacher (10)

Integrating learning technologies with the wall plane is the primary concern when this pattern is considered for design, where visual performance is questioned as well as the performance of the learning technology. Teacher (19) discusses the location and size of her TV screen with respect to students' desks and workstations in her chemistry lab saying *"The TV… this is not a really good spot… if you're sitting back over there…of course you have to turn your desk around and look up there. And if you're sitting over on that side of the room, it's small. So I pushed my VCR and now I project through the computer. So that's for the smart board. So it's a lot bigger and the kids like it… But it's such a small [TV]. And looking up and all that stuff –it gets awkward. So everybody has to turn around and all that stuff. So that's a problem."*

Teacher (21) expresses a problem with the location of her TV screen saying *"My TV sits so close against the wall that it doesn't turn; it doesn't swivel. So there's no point in it being mounted on a swivel. To be perfectly honest, I've never once used it, other than when kids have said, like when we had 9-11 and the kids wanted to watch the coverage. I've used it like that. But I've never had to use it as part of a lesson."* She captures this situation in Figure 5-21.

Figure 5-21 TV screen mounted on a swivel against the wall- Image captured by Teacher (21)

In summary, decisions regarding integrating of learning technologies with the wall plane in the space should consider visual performance of occupants as relates to height and angle of inclination and mounting location in relation to furniture layout. Table 5-14 and

Figure 5-22 illustrate pattern formulation.

Table 5-14 Height and Distance of Learning Technologies- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
- Direct -Direct-to-social	- Learning technologies may not be visually accessible to users due to mounting conditions (height, distance, surface qualities, angle and distance of integration with room boundaries). -Learning technologies might be visually obstructed by circulation or other activities in the room.	-Design for visually-direct and ergonomically-designed access between users and learning technologies. - Separate the main flow of circulation and other activities in the room from the typical visual line between users and learning technologies.

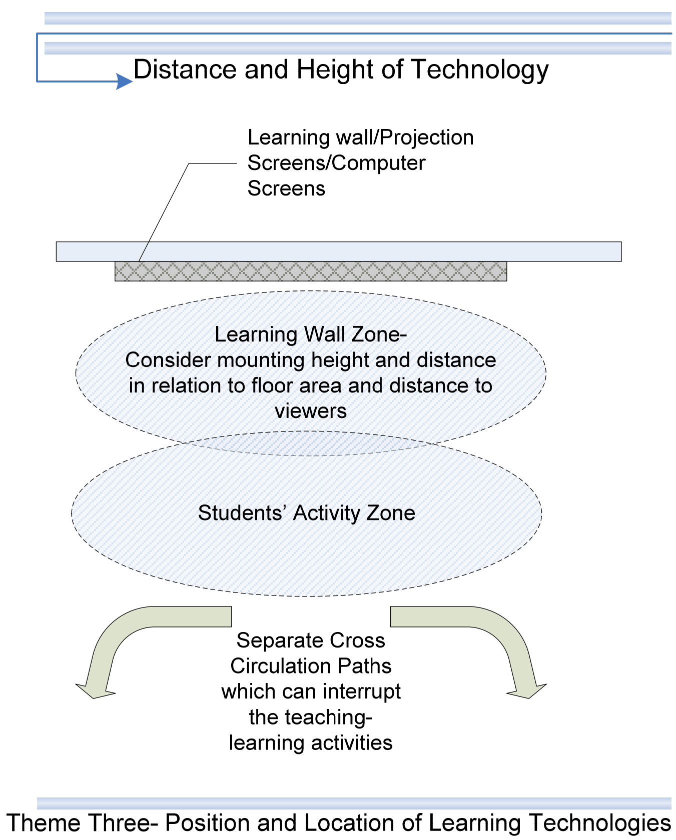


Figure 5-22 Distance and Height of Technology

5.3.3 Availability of space and designated locations for technologies

Integrating learning technologies in a contemporary learning environment requires attention to the pre-design of space and locations designated to host them. Although this pattern emerges in the study in the direct-to-social model, it is a requirement for successful spatial integration.

In this study, a number of situations emerge during the interviews which discuss the lack of pre-design for areas designated for locating learning technologies in the rooms. Teacher (9) discusses her current problem in locating her computer in the room saying *"I rarely use the computer, and I do once in a while, …a computer to project on, because I don't have a good place to set it up!"*

Teacher (18) explains the reason for not using a smart board saying *"the reason we didn't do a smart board in here was space. We thought we just didn't have the room for it… you know if we had one of the smart boards that were on wheels it would be in the way and then to mount a smart board we would have had to take that down, so we went that route".*

Teacher (5) describes a problem she encounters with the TV screen in her room saying *"When they put up the TV there was no place to put it, they couldn't block the closets on the right or the door on the left, they only could put it over here, which blocks the board,"* as she captures in Figure 5-23.

Figure 5-23 TV screen blocking visual access to the white board- Image captured by Teacher (5)

Whether for spatial, visual or acoustical performance, integration of learning technologies such as TVs in the classroom space as an after-thought can cause conflicts between technologies and create obstacles in the room, or lack of proper-use of these technologies in the teaching-learning process. Table 5-15 summarizes pattern formulation.

Table 5-15 Availability of Space and Designated Locations for Learning Technologies-Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
-Direct-to-Social	- Lack of pre-designed space to locate or upgrade learning technologies. - Placement of learning technologies in the space can be a visual obstruction to other elements in the space.	- Pre-design for integrating learning technologies in the space. Take into considerations issues such as visual access, circulation, patterns and modes of use, potential upgrade or replacement.

5.3.4 Connection between technologies

With the rapid advancement in development of learning technologies, communication between these technologies is growing in importance to teachers' productive performance. This pattern thus is concerned with integration potential between different learning technologies, as well as with the space. It is also one of the most occurring patterns in the three teaching models investigated.

Connected technologies challenge spatial performance when it comes to integrating these technologies to the envelope as well as the circulation and furniture components of the interior system. The following discussion offers a number of examples to highlight the effect this pattern can have on the space.

Teacher (8) discusses the ability of projecting information and data from different learning technologies saying: *"I use the graphing calculator more than computers…. I can project the calculator screen onto the TV monitor that is in my classroom."* Also she mentions that *"I would like to have a better way to project the computer like a projector. There is lots of information out there that I would like to use"*.

The possibility of connecting these technologies encourages teachers to utilize them in more efficient ways. Teacher (5) discusses her missed opportunities in using more of the technologies in her classroom because of connection issues saying: *"I would like to use the TV more in order to be able to use the computer more and do the animations and so on, but I have to plan those because there is no connection between the TV and any computer, so in order to use that I have to generate everything I need on our school lab top in order for them to schedule it for me on that day ... And if I wanted to do anything on the internet, they have to hook up a cord that goes across over here and over to one of the computers, so it is very complicated for me to use the TV."* On the contrary, teacher (7) is investing in such opportunities as she describes saying: *"I put my lecture notes on this computer, and have them projected to this television set on this side of the room [pointing]. There is an Elmo …hooked to the projector … which projects on this screen right here [pointing]."*

Teacher (9) describes a situation in her room pointing out a potential need for connecting multiple technologies for a certain function and for easier performance. She explains saying *"That computer is hooked up to the TV, so I can project it to the TV on that one! But it's a pain to work back and forth between that and the projector. I work with the overhead projector a lot"*. While teacher (13) describes his ability to establish this kind of connectivity saying *"we can hook up to [the projector] with a VCR and TV then and we can access and use it for group instruction. We decided to point it in this direction because we thought we could have more kids maybe viewing it at the time. And then we also have one on a cart so if we want to use a small group instruction and show an instructional video there we could."*

The opportunities which wireless networks can offer in such situation also emerges. Teacher (10) describes the network connectivity in his aviation lab saying *"Everything we have here is on a network. All of them have access to the internet."*

The issue of central control of such connection arises. Teacher (13) discusses this issue by saying *"we have to hook up our LCD projector to one of the student computers. I guess it would be kind of nice to have one computer, you know, that is your terminal and then that is used for instruction purposes and for display. I think that that would be a kind of a nice thing."*

Teacher (25) designs his own central control station with all learning technologies needed in his physics lab as he captures in Figure 5-24. He describes his desicion saying

"If I had a little bit of options—most of the teachers really want this projector hung. Well I have all these other things that I want to be able to use with it, and I don't want to figure out what kind of cabling I'd have to have to get all this to be able to be projected. And then the camera would be lost. But I could get by with a movie camera and a small tripod, and leave it on the station, and move the station off to the side. And then hang this and not have to worry about the camera".

Figure 5-24 Central control station with connected learning technologies created by Teacher (25)

Teacher (24) discusses issues of mobility which connected technologies can offer saying *"This is just a tablet PC and what I can do with this, is attach one of these Linxus units to the projector. And I could sit … I mean in theory I could even walk around and do this, but you can write on them here with a tablet, with a stylus, and it projects up to the projector and then onto the screen".*

Another opportunity also emerges with connecting learning technologies which is also related to mobility and is monitoring of students. Teacher (18) describes that saying *"In a typical class we're using the…almost exclusively now, the projector with the computer…Either using PowerPoint or writing on the screen. I find that if I'm writing on the screen I'm watching the kids at the same time or talking with them. If you're writing on the board you turn your back to them".*

Another advantage of connecting learning technologies as described by teacher (3) is permanent display. He discusses that saying *"We are required to display the class* *objectives… it is very convenient to have the television hooked up to my desktop computer, so I can leave that up continuously, instead of writing it on the board."*

An important issue also emerges in the discussion of this pattern, which is wiring and hazards related to exposed wiring in a classroom environment. Teacher (13) discusses that saying *"there's no place to put the cords. And that's an issue and I wouldn't be surprised if it's more of a fire issue and a hazard. Kids kick under the desks."* She also captures the situation in her classroom in Figure 5-25.

Connectivity between learning technologies in the space offers solutions to some of the major problems identified in the design of learning environments. It can offer solutions for issues such as communication, mobility, monitoring, as well as visual performance and safety of occupants. The space layout and proportions can also be altered accordingly. Table 5-16 discusses the potential this pattern can have for successful integrated design.

Table 5-16 Connection between Technologies- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
- Direct -Direct-to-Social - Social	- The need for connecting multiple learning technologies to enhance performance. - The need for providing central control of connected learning technologies. -Connecting learning technologies can enhance issues like mobility and monitoring in the learning environment. - Exposed wiring and hazards associated with it.	- Design the infrastructure and conduits which support connecting learning technologies across the room, either through hard wiring or wireless networking. - Provide means of central control; either a central location where learning technologies can be connected and operated from, or remotely through wireless networking from a central device. - Design for integrated conduits for connecting computer stations and other learning technologies across the room. Integration can be through the walls, floors, ceilings or furniture and work stations.

Figure 5-25 Wiring at students' computer stations- Images captured by Teacher (13)

5.3.5 Controlled lighting conditions

In a technology-rich contemporary learning environment, lighting conditions are important to ensure proper occupants' visual performance when they are in use. For that, this pattern emerges for the three teaching models. The pattern also influences spatial performance when it comes to integrating these technologies with the openings and the furniture.

Issues of glare and reflections usually require controllability either of the lighting source or the surface viewed such as projection or computer screens. In Figure 5-26 teacher (8) captures a glare situation on her white board which makes her abandon the use of the projector. She describes the situation saying *"I try to use [my overhead projector] to project… There is a big round glare on the board. I don't use it so much anymore, you see I use my calculator so much, and now I have the software that projects the calculator over the TV screen"*.

Figure 5-26 Glare created over the white board during projection- Image captured by Teacher (8)

Almost all interviewed teachers express their desire to have some degree of controlled lighting conditions in their rooms. In his aviation lab, teacher (10) describes the situation saying *"It's very very bright in here. We pull down the blinds."* Teacher (23) discusses the need for this kind of control in his room saying *"Usually you have to keep that window shade drawn for projection purposes and because by the afternoon the light* *coming through there puts a glare… it's in the kids' eyes that sit on the tables opposite the windows. It's not a helpful thing"*. Teacher (4) uses the term 'dimming' to describe the situation in his chemistry lab as the teaching-learning activity requires saying *"There are some things that require dimming especially in chemistry with the flames… I just pull down the shades."*

Teacher (19) captures a window in her chemistry lab in Figure 5-27 and explains the situation saying *"when it gets afternoon I have to close the blinds, even if I've opened them in the mornings. The morning's not too bad, but by 1:00 it's really getting sunny and the glare… For me looking this way at the students, if I'm up at the board and stuff, it's a glare for me; it bothers me… And not so much I guess the students, but then it also creates a glare on the board—the smartboard or the board. Or if you're looking at a video you pretty much have to close it too"*.

Figure 5-27 Position of a background window as a light source- Image captured by Teacher (19)

Teacher (16) starts explaining controllability of artificial lighting in the space saying *"when I do PowerPoint I can turn off those lights, …natural light's enough for them to see to write notes but then it's kind of darker on the screen so they can see what I'm writing"*.

Light zones is another strategy used to control artificial lighting in a classroom condition; where the space is divided into separate lighting sections which can be controlled individually in order to provide different levels of lighting conditions in the space. Teacher (10) lacks this opportunity in his aviation lab and says: *"The light is controlled by one particular switch over there, so we can't shut down part of the lights down to make it for them easier to see, and still be able to write… it's kind of a problem but we can overcome it."*

Even distribution of lighting over the surface of a learning technology is another issue which emerges repeatedly in the data. Teacher (22) discusses this situation in her room saying *"whatever is on the smart board might be a little bit difficult to see. And the room isn't too dark that the kids can't write with both lights turned off. But sometimes I do turn those on and there's a slightly different… One of them I have a better view of the smart board than the other switch"*. Teacher (21) installs a track light over the white board for even lighting distribution as she captures in Figure 5-28. She explains saying *"I installed the track lighting. I made a special request and I installed that because I've got dead spots on my board that even on the brightest day, it's hard to see. It looks like my board is shaded right there. And I think part of it is where that ceiling does come down. It blocks some of the light. But I had students that couldn't see very well, so I did those lights. It's a temporary fix; it's not great. But it does the job"*.

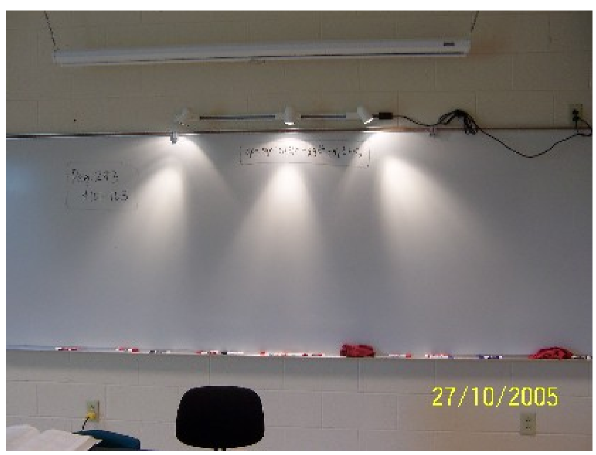


Figure 5-28 Track lighting installed by Teacher (21)

The quality and position of learning technologies also play a role in the visual qualities in the room. Teacher (25) explains saying *"The projector is not as bright as it should be, so we have to turn part of the lighting off. We have 2 light switches, so we can cut off either 2 or 1. That works pretty well."* Teacher (19) also explains another situation related to the position of her projector saying " *I mostly need to shut down the lights all the time…when [projecting]… having that [projector] up there instead helps, usually you've got this little circle of reflected light that's pretty much gone with it up high like that, which really helps"*.

Having controlled lighting conditions in the learning environment is critical due to the high variation in activities and the need for different lighting levels to match different tasks taking place in the room. Figure 5-29 and Table 5-17 represent pattern formulation.

Table 5-17 Controlled Lighting Conditions- Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
- Direct -Direct-to-Social - Social	- Need to control natural lighting conditions - Need to control artificial lighting conditions - Need to enhance visual qualities provided by specifications and locations of learning technologies	- Provide accessible, operable shading devices in at the openings to accommodate different lighting conditions throughout the day. - Provide lighting dimmers across the room. Especially at the boards or projection surfaces. - Divide the space into multiple lighting zones in the space to accommodate different activity and display levels in each. - Locate learning technologies at distances and heights which enhance their visual qualities.

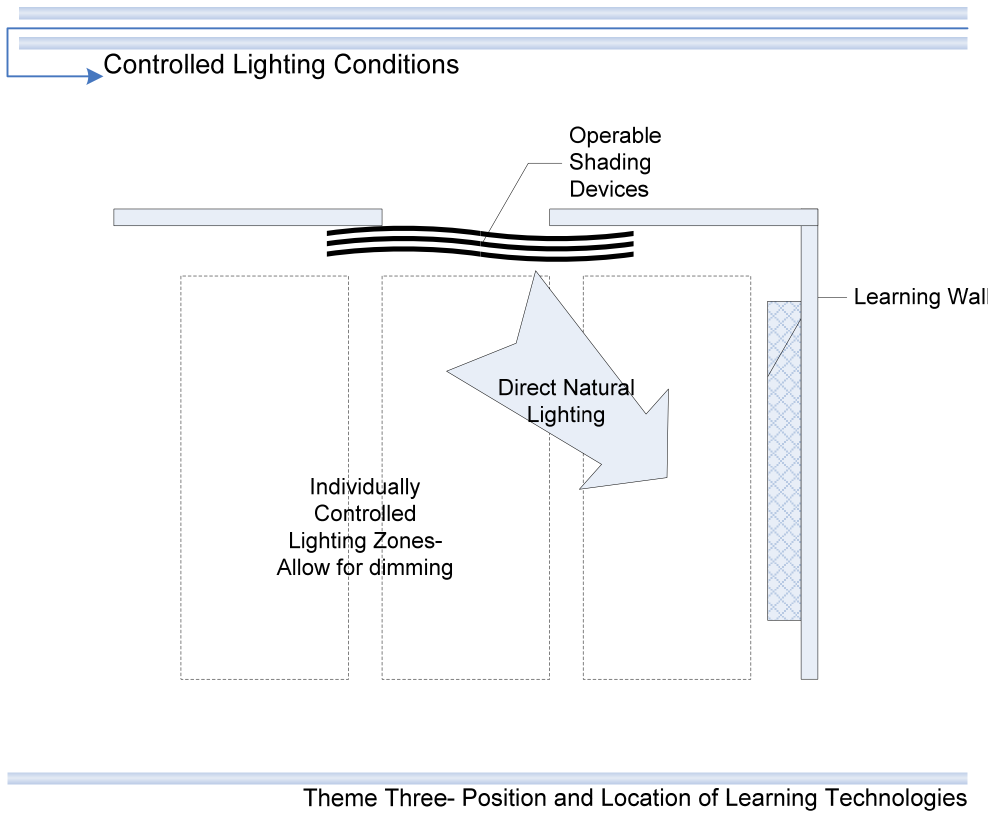


Figure 5-29 Controlled Lighting Conditions

5.4 Theme Four- Modes of Use

This set of patterns reflects design responses to patterns of events occurring in the space with respect to how occupants utilize learning technologies for specific activities. Patterns emerging are as listed in Table 5-18

Table 5-18 Patterns Emerging under Theme four-Modes of Use

Theme Four **Modes of Use**
1.Multi-use Technologies
2.Monitoring
3.Permanent Display

5.4.1 Multi-use technologies

Teachers of the direct model discuss the option of using minimal number of technologies which can perform multiple tasks for their teaching-learning goals. This can influence decisions related to space design when fewer technologies are required to be installed in the space, as well as planning for connections between them or not.

Mostly, teachers discuss the Smart Board as a technology capable of performing this. Teacher (2) says *"I have a smart board in the front of the room, and that is my main board….The reason for that is twofold; one, it allows me to take advantage of PowerPoint and things like that, it additionally allows me to save what am doing or access into my website"*.

Another way of establishing multi-tasking with learning technologies is layering. In Figure 5-30, teacher (23) captures an image of his LCD projector and explains how he uses it as part of the layering technique saying *"[the LCD overhead projector] is set up so that it projects from the top of the whiteboard to the bottom of the whiteboard. And that allows me to use the mimeo. And I can write on the whiteboard. So I can actually project on the whiteboard instead of pulling down the screen... So anything that I project up there I can take a marker and write on, or I can use the mimeo markers and use the mimeo screen, and navigate my way through mimeo and use the interactive mimeo"*.

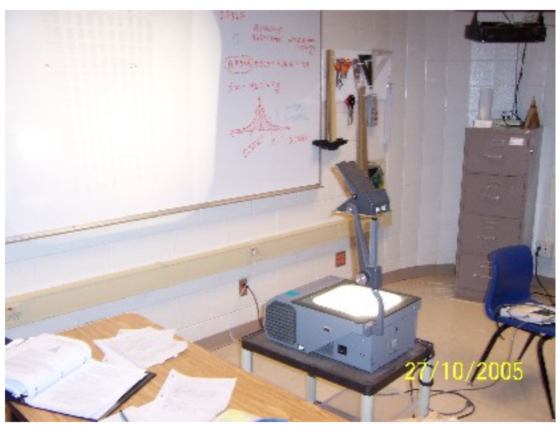


Figure 5-30 LCD overhead projector used for layering over the White Board- Image captured by Teacher (23)

In the integrated design of learning environments, the use of multi-task technologies should be considered when available. Required floor area and room layout are thus influenced due to the decrease in the area designated for placement and mounting of more technologies. Table 5-19 summarizes design criteria and recommendations for this pattern.

Table 5-19 Multi-use Technologies- Pattern Formulation

Teaching Models (Context)	Constraints (Systems of Forces)	Recommendations for Integrated Design (Configuration)
- Direct	- Number of learning technologies installed in the space is minimized - Furniture layout and circulation are oriented towards this primary learning technology.	- Define a location for this primary technology, whether it is built of one layer or is multilayered. - Design for integrating a furniture system which integrated visually and spatially with and is oriented towards this primary technology.

5.4.2 Monitoring

Monitoring of students' work at their computer terminals is an issue for teachers in the direct-to-social model. This pattern influences spatial integration decisions when it comes to furniture arrangement. Some of the layouts which teachers choose for their learning environments are primarily derived by this pattern.

Teacher (10) explains his experience with the layout of his aviation lab saying *"Last summer, I redesigned all of this [the computer stations area] so you can stand over here to see every monitor, all of them at one stop."* He captures this in Figure 5-31.

Figure 5-31 Layout of students' computer stations designed to enable direct monitoring- Image captured by Teacher (10)

Figure 5-32 illustrates a computer station where teachers are unable to monitor their computer lab, teacher (13) describes the reason for a particular layout of her students' computer stations saying *“we found that this particular shape of the computer aside from that one computer, we don’t have very many problems with kids going on inappropriate sites because we have access to see where they are at all times. We just have to turn our heads slightly and I can see where every kid is on their computer and see if they are with me on that same page”*. Teacher (15) who shares the same space agrees saying *“the idea is to create a space with twenty-two computers in this case where from any spot I can monitor them all. And we’ve done a pretty good job”*.

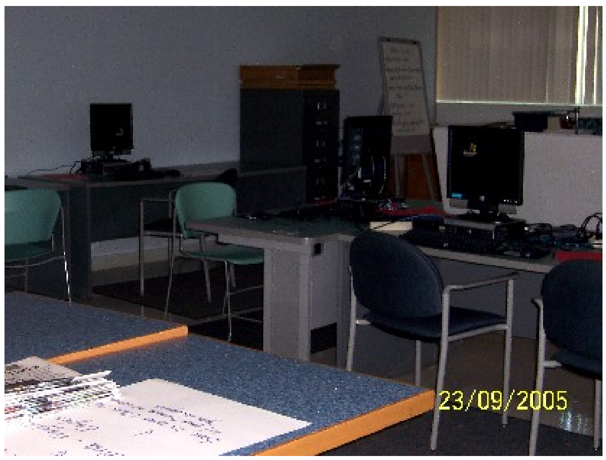


Figure 5-32 Layout of students' computer stations for monitoring- Image captured by Teacher (13)

Similarly, teacher (14) explains how the layout of his students’ computer stations supports monitoring saying *“My computers around the perimeter so that we can do instruction. It’s set up so that I can see every computer. I can see.”* He illustrates this preferred layout in Figure 5-33 .

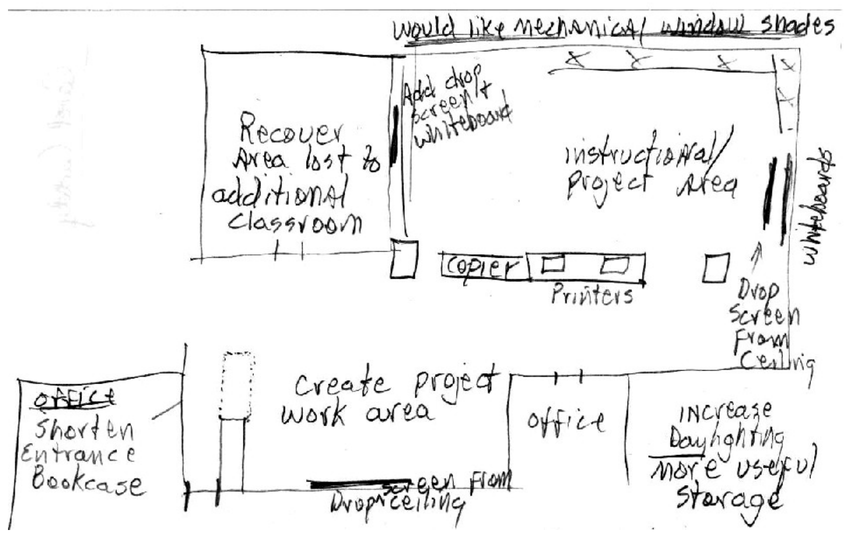


Figure 5-33 Perimeter layout of students' computer station for monitoring- Illustration by Teacher (14)

Monitoring of students’ activities on the internet is growing to be a major concern in designing contemporary learning environments.

Integrating students’ computer stations with the wall or floor planes and through the furniture system at the room perimeter is one of the most occurring design decisions derived from the need for monitoring students’ computer screens. Other scenarios include integrating them with the floor system at the center of the space.

Table 5-20 represents design criteria and recommendations when monitoring is considered.

Table 5-20 Monitoring- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
- Direct-to-Social	-When computers and the internet are the primary tools for students’ activities, monitoring is an issue to be considered for spatial design. - When remote communication is not an option, physical presence of the teacher is a must for each student.	- Design for a layout which minimizes teacher’s circulation distance for monitoring. -Provide direct physical and visual access for teacher to each computer screen. -Integration with the wall or floor planes are determined thus according to the proposed layout for monitoring.

5.4.3 Permanent display

This pattern emerges in discussions with teachers from the social teaching model, where they express the need for a surface for permanent display within their learning environment, which calls for integrating it permanently in the space as a fixed or a mobile surface. Teacher (3) explains the importance of the white board in his microbiology lab saying *"the white board is so important in the lab, because sometimes you have to write instructions for the whole lab to be able to see"*.

This surface is integrated either with the envelope planes if it is a fixed surface or with the interior system components (furniture and circulation) if it is mobile in the space. Table 5-21 illustrates pattern formulation for permanent display.

Table 5-21 Permanent Display- Pattern Formulation

Teaching Models (Context)	**Constraints (Systems of Forces)**	**Recommendations for Integrated Design (Configuration)**
- Social	-The need for a surface to be used for permanent display within the space - This surface can be integrated in a fixed or mobile fashion.	- When fixed, designate a location for this surface to be integrated at the meshed level with the wall plane. - When mobile, design for its circulation pattern and potential integration with adjacent planes if needed.

As patterns are formulated, a number of configurations emerge as recommendations for different levels of integrating learning technologies with components of the interior and envelope systems in learning environments. Table 5-22 presents these potential levels as interpreted from the data. It also points out different performance mandates corresponding to each pattern.

As proposed in this table, in a participatory design process, the organizational scheme is meant to assist decision-makers, and primarily those who are not acquainted with the field of architecture and space planning, to get an understanding of decisions needed during the late phases of space planning and architectural detailing.

Normally, a participatory design process does not reach this level of detail due to lack of time, resources and knowledge of decisions needed to be made. The result is a number of after-thought design decisions which cannot address users' needs as has been repetitively demonstrated by participants in this study.

Table 5-22 Performance Mandates and Integration Levels for the Technology Integration Pattern

Themes and Pattern	Model	Performance Mandates						Levels of Integration with the Envelope and Interior Systems' Components								
		Vs	**Th**	**Ac**	**Sp**	**Sf**	**As**	**EW**	**EF**	**EC**	**EO**	**IF**	**IE**	**IC**	**IL**	**IH**
Access Restriction	D-DS	x			x	x		C	C	C/T						
Physical Access	D-DS				x	x								R		
Visual Access	D-DS	x			x			C		C/T					R	
Access Locations	D-DS				x	x	x	C	C	C		C		R		
Remote Communication	DS	x		x	x			CB	CB	CB		CB	CB			
Visual Communication	DS	x			x									R		
Wireless Mobility	D-DS-S				x			R	R	R		R/T		R		
Mobile Control	D-DS				x									R		
Remote Communication	DS	x		x	x			CB	CB	CB		CB	CB			
Area of Learning Wall	D-DS	x			x			M				R		R	C/R	
Distance and Height	D-DS	x		x	x			C				R		R		
Availability of Space	DS															
Connections	D-DS-S	x			x	x	x	C	C	C		R	R/C	R		
Lighting Conditions	D-DS-S	x			x			C/T/M	CB	C/T	R	R			C/M/R	
Multi-Use Technologies	D	x			x			C/T/M	CB	CB		R		R	C/M/R	
Monitoring	DS	x			x			C/T	CB			R/C/T		R		
Permanent Display	S															

KEY:

Performance Mandates	Teaching Model	Integration Levels	Envelope System	Interior System
Vs= Visual	D= Direct	U= Unified	EW= wall	IF=Furniture
Th= Thermal	DS= Direct-to-Social	M= Meshed	EF= Floor	IE= Equipment
Ac= Acoustical	S= Social	T= Touching	EC= Ceiling	IC= Circulation
Sp= Spatial		C= Connected	EO=Openings	IL=Lighting
Sf= Safety		R=Remote	(windows and doors)	IH= HVAC
As= Aesthetics		CB= Case-based		

5.5 Assessment of Research Quality

This section discusses bias and bias control methods, describes verification procedures as recommended in the qualitative paradigm (Anfara, Brown and Mangione, 2002).

5.5.1 Bias control

As discussed previously in chapter four, it is essential to declare bias in this research towards methods and definitions in the discipline of architecture rather than education due to the researcher's educational and professional backgrounds. Also, it should be taken in consideration that the researcher is introduced for the first time to some of the teaching models described in this research. Prolonged engagement in the field as well as previous research bridge this gap in the researcher's knowledge. Yet, bias towards familiar teaching practices should be declared. In the qualitative paradigm, bias control is also considered a procedure towards establishing triangulation.

The following tactics are considered for bias control during the research process:

1. Participants are asked to engage in an interview process which is purposely designed to be open ended. One of the procedures during the interview is data narration; where participants are invited to "monologue" while reflecting on their experiences in their learning environments. They are also asked to capture images of spaces which enforce the understanding of these reflections with minimal bias.
2. Data triangulation, which is an essential reliability task in the qualitative paradigm. As discussed in the following section, information captured through the process and considered "incomplete" or "weak" can be completed.
3. Images and descriptions of learning environments provided by participants during the interview process provide detailed, thick, rich description of the context of the study and describe a full picture of the setting.

5.5.2 Assessment procedures

Assessing the research quality (validity) in the qualitative paradigm is established through four criteria; credibility, transferability, dependability and confirmability. The goal of this process is to ensure that the unexplored bias does not influence the work, and to ensure that the case matches the constructions of the individuals in the context.

Generally, eight verification procedures can establish this assessment in the qualitative paradigm. It is recommended that at least two should be followed in any study (Anfara, Brown and Mangione, 2002). Table 5-23 assesses this study for the four criteria described above through the recommended eight verification criteria. This table is followed by a discussion of two major procedures established in this study; thick description of the research context, and members checks.

Table 5-23 Assessment of Research Quality

Assessment Criteria	**Verification Procedures**	**Research Check-list**	**Description**
Credibility	Prolonged engagement in the field	x	Interview with teachers at learning environments
	Use of peer debriefing		
	Triangulation	x	Bias control, multiple data gathering modes
	Member Checks	x	Follow up survey
	Time sampling		
Transferability	Provide thick description	x	Participants image narration and graphics
	Purposive sampling	x	Teachers at governor schools in Virginia
Dependability	Create and audit trail		
	Code-recode strategy	x	Two iterations of code mapping
	Triangulation	x	Bias control, multiple data gathering modes
	Peer examination		
Confirmability	Triangulation	x	Bias control, multiple data gathering modes
	Practice reflexivity		

5.5.2.1 <u>Thick description of research context</u>

This procedure is an essential task for establishing research quality and rigor in the qualitative paradigm. The essentiality depends on “our intent to bring understanding about the case and on the degree to which this statement helps clarify the story or differentiate between conflicting meanings” (Stake, 1995, p. 112).

Learning environments are generally complex environments. In an attempt to gain an understanding of the nature of these spaces, rich-thick description of their context is needed. Primarily this context is translated to patterns of events and patterns of space. Data gathering is done through a number of modes in order to provide this kind of understanding, as illustrated in Table 5-24 which is a matrix of research questions and data sources as designed to meet this verification procedure.

Table 5-24 Matrix of research questions and data sources

Research Questions	Data Gathering Modes				
	W	**I**	**N**	**G**	**P**
Participants' Demographics	x				
1- Participants-by-Pedagogy					
(a) Pedagogical practices adopted by the research sample	x	x			
(b) Decisions regarding learning technologies and the learning environment		x	x	x	x
2- Participants-by-Technologies					
(a) Learning technologies needed to support pedagogical models	x	x	x	x	x
(b) Architectural decisions for integrating learning technologies in the space		x	x	x	x
3- Participants-by-Space					
Integrated architectural systems in a technology-rich learning environment		x	x	x	
4- Participants-by-Occupancy					
The design of learning environments in support of pedagogical practices	x	x	x	x	

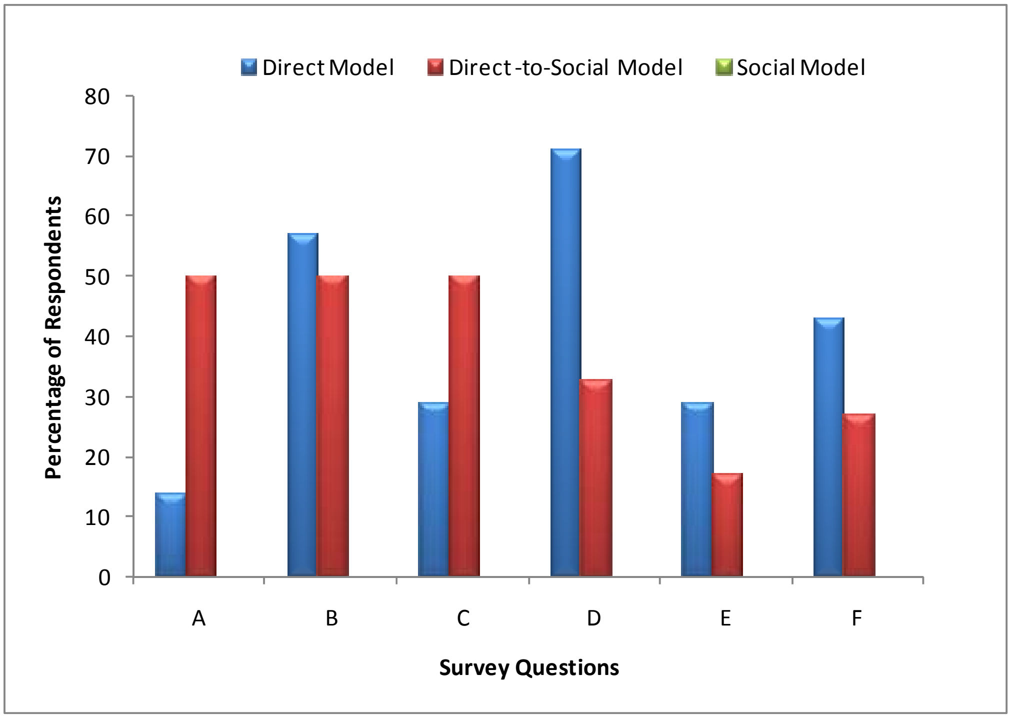
Note:
W=Initial web-based survey,
I=Teachers' interviews,
N= Image narration
G=Graphical illustration,
P= Post-study web-based survey

5.5.2.2 Members checks

The procedure is established by a follow-up web-based survey (Appendix C) which was sent to participants after the analysis phase. Participants within the three teaching models are asked to prioritize patterns which emerge from the study according to their spatial needs and teaching practices in verification of the research findings.

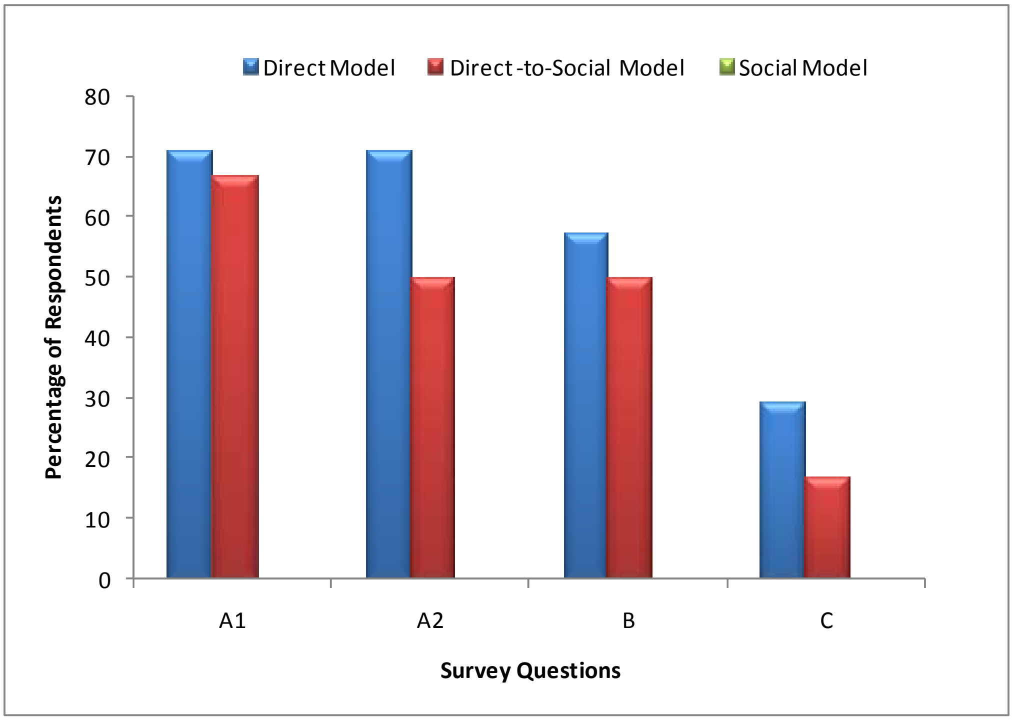
The following figures represent results of this survey in respond to the four emerging themes. There was no input received from teachers adopting the social model as indicated in the charts.

In the tables, the first column represents the legends illustrated in the charts which correspond to specific emerging patterns. In the second column, questioned patterns are listed. The last column lists specific survey statements which correspond to the emerging patterns.



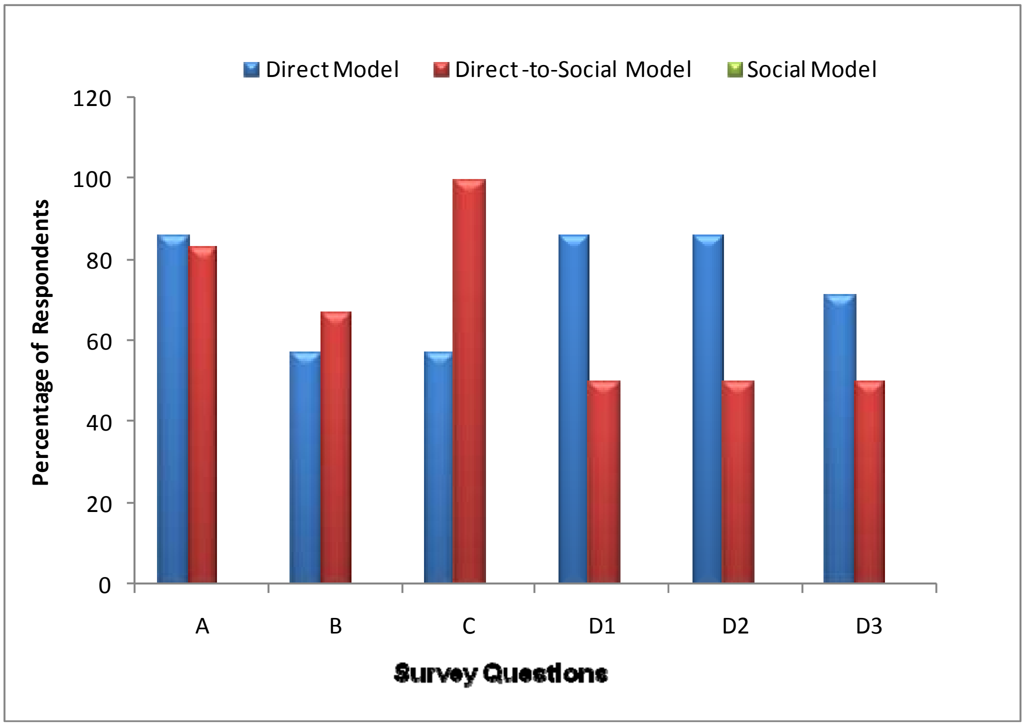
Legend	Pattern	Survey Question
A	Access Restriction for Safety and Maintenance	Restrict access to some technologies for safety and performance issues
B	Physical Access to Fixed Technologies	Enable easy and comfortable physical access to learning technologies
C	Visual Access to Technologies	Enable proper and comfortable visual access to learning technologies
D	Access Location/Portals	Provide outlets for electricity and other services
E	Remote Communication Between Students and Instructor	Enable me to communicate with my students through remote devices
F	Visual Communication between Students and Instructor	Provide proper visual access to other occupants and technologies

Figure 5-34 Participants' input in the follow-up survey- Theme One, Accessibility and Communication



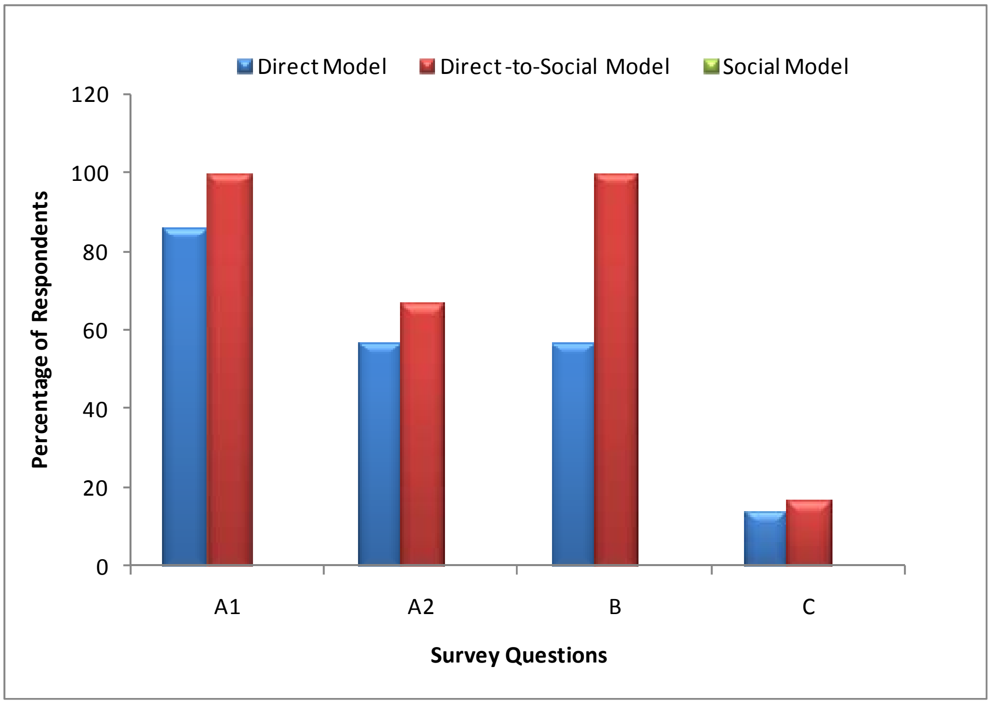
Legend	Pattern	Survey Question
A1	Remote/Wireless Mobility	Enable me to access learning technologies remotely
A2	Remote/Wireless Mobility	Provide remote and wireless enabled technologies
B	Mobile Control of Fixed Technologies	Enable me to control learning technologies remotely
C	Remote Communication Between Students and Instructor	Enable me to communicate with my students through remote devices

Figure 5-35Participants' input in the follow-up survey- Theme Two, Mobility



Legend	Pattern	Survey Question
A	Area of Learning Wall	Provide enough space for the learning wall
B	Distance and Height of Technology	Mount technologies at proper height and distance relative to room layout
C	Availability of Space and Designated Location for Technologies	Designate space and locations for learning technologies in the room design
D1	Controlled Lighting Conditions	Enable control of lighting conditions for better visual performance when technologies are in use
D2	Controlled Lighting Conditions	Provide multiple lighting zones in the space for better performance when technologies are in use
D3	Controlled Lighting Conditions	Design for controlled natural lighting penetration in the room

Figure 5-36 Participants' input in the follow-up survey- Theme Three, Position and Location of Technologies



Legend	Pattern	Survey Question
A1	Multi-use Technologies	Provide learning technologies which can function for multiple purposes
A2	Multi-use Technologies	Provide technologies which can function with different group sizes
B	Monitoring	Enable Monitoring of students' computer screens
C	Permanent Display	Provide technologies for permanent display

Figure 5-37 Participants' input in the follow-up survey- Theme Four, Modes of Use

In summary, four major themes emerged from the data analysis process. The first theme (Accessibility and Communication) describes design patterns for enabling or restricting accessibility to some learning technologies whether visually, physically or even remotely. This is typically preferred for safety issues, to minimize distraction, allow for more convenience or higher comfort levels when these technologies are in use.

All six patterns constituting this theme were seen important for the research participants. Participants of the direct model indicate that the integration of appropriate access points for electricity and other services within their learning environment is of highest priority. While teachers adopting the direct-to-social model chose three patterns to be of equal importance when it comes to integrating learning technologies in the space, these are Access Restriction for Safety and Maintenance, Physical Access to Fixed Technologies, and Visual Access to Technologies.

The second theme (Mobility) reflects teachers' and students' desire to be able to move freely during teaching-learning activities. In contemporary learning environments, there is a strong potential to establish such mobility due to the availability of wireless communication. When it comes to mobility issues, teachers in the direct model indicate that the first two patterns of the four constituting this theme equally represent their highest priority; these are Remote/Wireless Mobility and Mobile Control of Fixed Technologies. While teachers adopting that direct-to-social model indicate that the first pattern Remote/Wireless Mobility is of most importance towards integrating learning technologies in the space.

The third theme (Position and Location of Learning Technologies) primarily describes patterns for spatial performance when it comes to integrating learning technologies within the space. It also addresses issues like mounting heights, distance from viewers and angle of inclination. Teachers in the direct model perceive that two out of four emerging patterns are equally important for the design of their learning technologies when integration is considered; these are Area of Learning Wall and Controlled Lighting Conditions. On the other hand, teachers adopting the direct-to-social model indicated that Availability of Space and Designated Locations for Technologies is their highest priority.

The last theme (Modes of Use) reflects design responses to patterns of events occurring in the space with respect to how occupants utilize learning technologies for specific activities. Three patterns emerged under this theme. Participating teachers practicing the direct model of teaching indicate that the provision of technologies which can function for multiple purposes and different group sizes is of high priority to their teaching plans. Teachers adopting the direct-to-social model perceive similar importance to this theme, yet they equally weigh the importance of the Monitoring pattern.

Although these findings precisely address the research sample, it is expected that they may alter with the involvement of a larger or a broader sample, or when incorporating other sets of patterns (patterns of the physical space and patterns of space occupancy). This wider scope of analyzed data sets is expected to offer a deeper understanding of patterns of events, and consequently patterns of space.

Also, with the advancement of learning technologies and the design of learning environments these findings may change. Yet, the proposed methodology is expected to function as efficiently.

CHAPTER 6 CONCLUSION AND INTERPRETIVE READINGS

This conclusion discusses the results presented in previous chapters, offers interpretive readings for the research process and findings, and summarizes concepts and theories for developing a design pattern language. It also states the contributions of this research, and suggests future research that may extend application and development of an intelligent computerized design system for integrating technologies in learning environments.

6.1 Research Summary

Learning environments are spaces with a rich potential for systems' integration, which is proven to be a major component of building intelligence. In order to be able to respond to current pedagogical practices, these systems should be integrated in a manner flexible enough to accommodate different occupancy and activity patterns in the classroom, to adapt to variable teaching/learning dynamics, and encourage individual teaching instances as efficiently as team teaching.

A form of artificial intelligence, the goal of this study is establishing the possibility of linking decision-support structures like the one proposed to computing environments; a goal which is beyond the objectives of this particular study. The methods described in this study represent knowledge collection and structuring that once completed, can be adapted to such as intelligent computing environment.

The study is qualitative in nature, and focuses on integration patterns of learning technologies with the envelope and the interior systems as they pertain to occupants' performance. The findings are then translated into the design language in the form of a pattern language at the building systems scale to support the early design phases of a technology-rich learning environment. The variation of teaching-learning modes is taken into consideration.

The following particular research objectives and tasks are addressed throughout the study:

1. Defining performance mandates in architectural spaces, integrated building systems, their levels of integration, and their position in an intelligent design process.
2. Defining contemporary learning environments, their components, and variations in pedagogical practices and learning technologies hosted within them.
3. Developing design patterns for integrating learning technologies with the interior and envelope systems in the space as responds to pedagogical practices in learning environments. Finally, identifying potential integration levels of these technologies with the components of the envelope and interior systems.

The dissertation is presented in six chapters, each of which discusses one of the research tasks above; Chapter Two reviews the basic concepts of human problem solving and intelligent design problems. It also presents the pertinent research on integrated building systems, and discusses its position in the intelligent design process. The literature suggests that the validity of the equation "Building systems' integration = Building Intelligence" is worth pondering, due to the proven high performance of integrated building systems which is the primary goal of intelligent building design. Building systems' integration also takes into account two major considerations for establishing building intelligence which are user-based consideration, such as users' requirements, occupants' effectiveness and productivity as well as performance of the space, whether that is thermal, acoustical, visual or spatial. This chapter also discusses pattern language and its applications in designing learning environments as an efficient means of visually communicating and translating the language of design.

Chapter Three reviews contemporary pedagogical approaches and their influence on the design of today's learning environments. It also defines the term 'Learning Environment' with respect to its proposed four major components; the space, the occupants, the technologies, and the pedagogy, which are the four analysis units adopted throughout the study.

This chapter also outlines the major pedagogical models which are practiced in learning environments today. Since diverse teaching-learning activities take place when adopting each teaching model, the architectural space should adapt to this diversity and thus respond to the pedagogical component. Teaching models discussed in the literature at this state of knowledge are the direct, teacher-driven model, the social model, and the radical, student-based model as well as the transitional pedagogical practices within.

Chapter three also offers a discussion of relevant literature in the area of design patterns of learning environments which form the theoretical background on which the design of the data gathering instruments is based. Design pattern language is the tool developed for communicating the research findings with different parties involved in the decision making process of designing a technology-based learning environment. It is a broader goal of this study to adapt this language to an intelligent computing environment, which supports the early design phases of learning environments.

Chapter Four reviews qualitative methods adopted for the study, describes the research sample, data organization and reduction processes. It also discussed the research and analysis processes. The research questions are also identified in this chapter. They are designed to reflect and question the four components of learning environments. Specifically, the research questions are:

The study specifically addresses the following research questions which aim to understand and interpret the performance within learning environments when learning technologies are in use:

1. Participants-by-Pedagogy: (a) what are the pedagogical practices adopted by the research sample? And, (b) how do these practices influence decisions regarding learning technologies and the learning environment?
2. Participants-by-Technologies: (a) Which learning technologies are needed to support pedagogical models? And (b) what architectural decisions should be considered for efficiently integrating learning technologies with other physical architectural systems in the space (the envelope and interior systems for the purposes of this study)?
3. Participants-by-Space: how do architectural systems integrate in a technology-rich learning environment?
4. Participants-by-Occupancy: how can the design of the learning environment support such practices?

Research data are also organized and reduced to reflect the same four components into four corresponding data matrices; participant-by-pedagogy, participant-by-technology, participant-by-space, and participant-by-occupancy patterns. These data matrices offer a reduced, organized format for the data chunks collected during the different data gathering modes throughout the study.

Multiple data gathering modes are utilized to establish triangulation for credibility, dependability, and conformability purposes. The analysis process in this study is biased towards methods known in the discipline of architectural engineering rather than the field of education due to the educational background of the researcher. This bias is declared in the analysis of the research data and is significant in the presentation of the findings.

Chapter Five presents the analysis process and research findings in the form of design patterns at the building systems scale, as well as the potential integration levels between learning technologies and the components of the envelope and interior systems.

Within patterns of technology integration, four major themes emerge; accessibility and communication, mobility, position and location of technologies, and modes of use. Each theme includes a number of patterns which describe integration potential which meets the major concept which the theme addresses.

The first theme; accessibility and communication describes design patterns for enabling or restricting accessibility to some learning technologies whether visually, physically or even remotely. This is typically preferred for safety issues, to minimize distraction, allow for more convenience or higher comfort levels when these technologies are in use. Emerging patterns are; access restriction for safety and maintenance, physical access to fixed technologies, visual access to technologies, access locations/portals, remote communication, and visual communication between teacher and students.

The second theme; mobility reflects teachers' and students' desire to be able to move freely during teaching-learning activities. With the availability of contemporary learning technologies, there is a strong potential to establish such mobility due to the availability of wireless communication.

The third theme; position and location of technologies, primarily describes patterns for spatial performance when it comes to integrating learning technologies within the space. At the pattern scale, it discusses issues such as area of instructional wall, distance and height of technologies, availability of space and designated locations for technologies, connection between technologies, and controlled lighting conditions.

The last theme; modes of use reflects design responses to patterns of events occurring in the space with respect to how occupants utilize learning technologies for specific activities. Specific patterns are multi-use technologies, monitoring and permanent display.

All emerging patterns offer design decisions derived from patterns of events interpreted from collected data sets, and aims at developing a tool that helps designers and other decision-makers in the early design phases of a technology-based learning environment. Chapter five also discusses assessment of research quality as recommended in the qualitative paradigm. In addition to the provision of thick-description of the investigated learning environments; members' check, purposive sampling, code-recode strategy and engagement in the field validate research quality for credibility, transferability, dependability, and confirmability.

6.2 Contributions

This study offers the research field, the profession, as well as other community members in a participatory process a scope of contributions. These contributions can be defined with respect to the role which the study played during different research phases towards pattern formulation. These roles are classified into the following and as illustrated in :

1. The Descriptive; this role offers a description of the current state of knowledge represented in data gathered from teachers at their learning environments. This data describe the context of the study as the first part of the rule for pattern formulation.
2. The Explanatory; where the study explains design criteria and constraints for integrating learning technologies in the space, and how this integration influences design decisions. These decisions are primarily dictated by teaching models practiced in the space. This part also presents what

Alexander describes as 'systems of forces' when it comes to pattern formulation.

3. The Prescriptive; where it offers design patterns for integrating learning technologies with components of the architectural systems (patterns of space). These patterns are designed to be communicated among participants in a design process of educational facilities; these can be designers, facility planners, teachers, students, school administrators, parents as well as other community members.

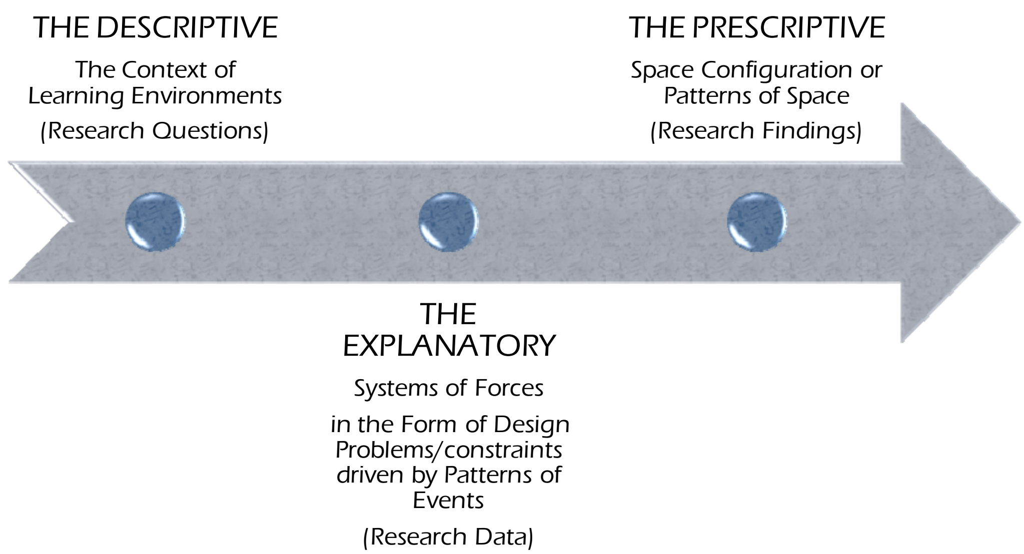


Figure 6-1 Logic model for the research process towards pattern formulation

Specifically, the study introduces the following to the body of knowledge:

6.2.1 The methodology

The methodology introduced in this study in addition to being participatory in nature, it is based on users' requirements and needs illustrated in patterns of events taking place in learning environments. It also considers the four components of learning environments as the main units of analysis. More specifically, it is based on three architectural design approaches:

1. Performance-based approach
2. Intelligent-architectural-design approach
3. Participatory-design approach

Although learning environments and learning technologies are rapidly advancing and altering. It has been a goal of this study to offer a methodology which can address this level of design despite such advancements through time.

6.2.2 Integration Patterns

The latest research in the area of design patterns for learning environments have proposed patterns which solely reflect architectural and planning variations. Patterns emerging from this study are derived primarily by variations in pedagogical practices in the learning environment and the use of relevant educational technologies. Also, patterns proposed in this study are the first to address the building systems scale, and different systems' integration levels.

In a participatory design process, patterns emerging from this study are meant to assist decision-makers to get an understanding of decisions needed during the late phases of space planning and architectural detailing. Normally, such design process does not reach this level of detail due to lack of time, resources and knowledge of decisions needed to be made. The result is a number of after-though design decisions which cannot address users' needs as has been repetitively demonstrated by participants in this study.

6.2.3 Design of Technology-Integrated Learning Environments

Learning environments are highly transforming from being the domain of the professional lecturer to a multimedia-intensive, highly collaborative facility used to produce and consume media-rich materials. Current trends in classroom design call for looking at technology as liberators, especially given the emerging wireless technologies. Dede (2002) further anticipates the emergence of more interactive technologies to support learners through their experience; he classifies these technologies as the familiar world-to-the-desktop interfaces for ubiquitous computing and the multi-user virtual environments interfaces (MUVE).

Such technologies are expected to dramatically transform the teaching-learning process as well as the design of physical learning environments from the typical desk-and chair layout, towards a more integrated, interactive environment. Ubiquitous technologies have the capability of integrating up to the unified level with components of the envelope and interior systems, which may significantly alter decisions regarding the furniture, circulation and lighting systems within the space in particular. The proposed design approach is designed to address these changes with minimal change as it is primarily based on users' needs and requirements.

Generally, integrating learning technologies should not be an afterthought to the design process; students today expect to utilize progressive technologies in their learning experiences; teachers are also becoming increasingly aware of the important role these technologies play in supporting their work. The proposed pattern language addresses these issues by considering the question of how learning environments can accommodate a variety of teaching modes and learning styles.

Since learning environments are spaces with a rich potential for systems' integration, this study proposes integration patterns as a design tool which aids in the integrated design of learning technologies, which are rapidly growing in importance, with the envelope and interior systems within the space. This tool is expected to grow in importance as well as learning technologies become more advanced and adapt to different pedagogical approaches practiced in learning environments of the future.

6.3 Interpretive Readings

In the duration of this study, learning environments have been investigated in a number of ways reflecting the proposed four major components. It is observed that the frequency of the emerging patterns in the interview transcripts vary according to the teaching models which teachers adopts. For example, some patterns emerge in all three models considered for analysis such as controlled lighting conditions or connection between technologies. Other models emerge in only one of these models, such as pattern of permanent display.

The priority of each pattern for each teaching model is variable. Data gathered for this research are insufficient for identifying the variables influencing these priorities. Also, since boundaries between these pedagogical models are blurred and cannot be definitely identified, it is not possible at this state of knowledge to claim reasons for these variations. The follow-up survey (Appendix D) is designed for member checks and to assess this variation for future research.

The study of learning environments is directly correlated with the pedagogical models taking place within them; patterns of space are driven by patterns of events. Based on that, how teachers reflect on their learning environments depends on how they perform in it; what are their teaching-learning activities and what their preferences are when it comes to using learning technologies as a tool.

The following is a number of random observations of how teachers in the three teaching models considered in this analysis, have reacted to their learning environments as corresponds to their pedagogical approaches.

Mostly, teachers adopting the direct model prefer the typical layout of the room; where the teacher's station occupies the room front. Consequently, they emphasize the importance of the room front and lock the location of the learning wall and most of the learning technologies at this position. Some also suggest the tiered benches for their students seating, which might restrict students' mobility and direct physical access to other components of the learning environment.

Moving towards a more social approach; teachers adopting the direct-to-social model encourage further students' engagement in the teaching learning process; teachers in this group engage group work in addition to direct instruction. Another approach among this group of teachers is providing students with real-world experiences through learning activities which correspond to their case-based teaching scenarios. It is a common observation among this group of teachers that they bring openness to their learning experiences through the space, whether through the envelope system and the openings within it which offers connection to the outside of the classroom boundaries, or by inviting teaching learning activities which take place outside the space. In both cases, the learning environment should connect to adjacent open spaces or invite outdoor activities inside it. Controllability for better performance for learning technologies is a design issues for this particular case.

Similar to that are the activities which the last group of teachers hosts in their learning environments. Yet, teachers adopting the social model invite more flexibility in the space for performing the teaching-learning activities at a number of levels; individual, small group, or large group activities. The space thus should he designed to accommodate these diverse activities, connect to the outdoors, yet be highly controlled to isolate the space when needed for visual and acoustical performances.

How teachers use learning technologies in teaching-learning activities is highly correlated with the pedagogical models they adopt, as well as their individual preferences, teaching traditions and habits. Frequency and ease of use of each learning technology are also major variables. For example, some participating teachers rejected the use of the smart board from their teaching activities due to issues like need of frequent screen alignment.

Visual, remote and direct physical access to learning technologies is an important issue for the performance of teachers and students and their interaction with these technologies. Remote and wireless abilities allow users today to move freely in the space, which offers a new potential for space layout and orientation of technologies with respect to occupants of the space; the most significant change is discarding the traditional wide perimeter desktop stations which is space consuming and with least flexibility when it comes to the activity patterns.

6.4 Discussion of Future Research

This study is a beginning to numerous future research opportunities in a number of fields such as knowledge support structures, design patterns and pattern language, building systems' integration and studies in the fields of education and learning environments as proposed in the following sections.

6.4.1 Intelligent knowledge support structures

The broad goal of this study as discussed earlier is the development and utilization of knowledge-support structures that can be used by architects and building engineers to make more informed, intelligent decisions concerning building design. A form of artificial intelligence, the goal is establishing the possibility of linking these decision-support structures to computing environments, which is the primary aim for future research since the methods described in this study only represent knowledge collection and structuring for such as intelligent computing environment.

6.4.2 Design patterns and pattern language

The proposed pattern language calls for further input and expansion based on a variety of research efforts in the same area. Further input from students and other users of learning environments, as well as architects, designers and facility planners can contribute to this work and help further develop the proposed pattern language.

Building on the proposed methodology, researchers will be able to investigate newer patterns derived from continuously emerging learning technologies. Also, further research is required to investigate patterns of integrating learning technologies with other systems in the space, such as mechanical and structural systems.

6.4.3 Building systems' integration

Higher complexity levels of the pattern language can be achieved by investigating potential for multi-system integration rather than only two-systems integration as the level which this study investigates (integration of learning technologies with components of the interior or the envelope systems).

This new approach towards integration can also be investigated on different building scales; starting with the facility planning and infrastructure levels, to the integration level of systems components. The proposed methodology can also be used for investigating other performance mandates within the classroom space such as thermal and acoustical performance.

This approach can also be applied to a variety of building types, as well as different spaces within educational facilities.

6.4.4 Studies in the fields of education and learning environments

The data reduction process resulted in four data groups, organized in the form of matrices which correspond to the four major proposed components of learning environments (pedagogy, learning technologies, the space, and the occupants).

Studies related to the pedagogy and occupants components can be further developed in collaboration with experts from the fields of education and psychology. Such studies can further enhance and develop the patterns of space by offering different interpretations of patterns of events taking place in learning environments. Thus more accurate and elaborate integration patterns may result.

As a concluding remark, learning environments are very active architectural spaces, dividing them into four components is only an attempt to simplify these complex environments, and architectural systems integration decisions can be one more step towards a more organized and informed decision making design process for such spaces.

Yet, design for human requirements in pedagogy-driven spaces essentially requires attention to patterns of events occurring in these spaces. Collaborative design can be another way to gain a comprehensive understanding of how these spaces operate and how integrated design can support these operations.

This research studied the integration of learning technologies which are rapidly increasing in importance for a successful teaching-learning process with only two systems in learning environments. This is considered a first step towards implementing the concept of systems integration in such an active space while demonstrating collaborative design and intelligent design approaches.