

Usability requirements for buildings: a case study on primary schools

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Abstract. This paper concerns an applied research aimed at applying the concept of usability, as derived from the standard ISO 9241/11, in the field of building design, namely primary schools. Starting from the concept that space characteristics play a very relevant role in learning performances, the study presented here developed an original methodology for the assessment of effectiveness, efficiency and satisfaction of buildings hosting primary schools, in order to create a school environment better supporting users in their tasks. Research core is the framework of usability requirements and their related markers, indicators and technical specification that has been formulated in order to check compliance of urban area, building, rooms and architectural details with users needs. Therefore, a detailed task analysis of pupils and teacher tasks has been carried out and two questionnaires addressed to a significant users panel have been formulated for satisfaction survey. Lastly, a matrix for an overall reading of gathered data has been set-up and criteria for usability assessment based on that data has been defined. The whole study has been developed within the case study of a primary school in the Naples city centre, whose contents and results are discussed.

Keywords: learning performances; education, task analysis; ergonomics, assessment

1. Introduction

School environment matching learning needs is a key issue in schools' design and refurbishment, since education outcomes are strongly affected by building performances in their whole [7], [15], [11], [12]. Tangible and intangible characteristics of learning environment must represent a supporting context of use for children's and teachers' activities. Therefore, if well tuned, relationships between children behaviour and characteristics and architectural layout and detailing (shapes, colours, dimensions, as well as lights and shadows, proportions or textures) can be a mean for strengthening learning performances in pupils as well as improving teacher's activities [15].

On this background, the concept of building's usability can bring a successful approach to the school design field. Building usability represents the suitability of a building for a specific use, that is the ability of building to help users in achieving their goals in a fully satisfying way [12], [15]. Usability approach addresses designers to create, by mean of built envi-

ronment, the best conditions for learning activities execution with the consequent enhancement of education outcomes [12], [4].

2. Applied methodology

2.1. General approach

Research presented here addresses usability requirements [1], [2] for primary schools, with specific reference to architectural, environmental and layout detailing.

The overall approach is based on the consideration that learning environment, of which school is the physical, tangible, component, represents the context of use of educational services provided to pupils [3], [7]. In this view, school usability is investigated in terms of effectiveness, efficiency and satisfaction, under the ISO 9241/11 perspective [10], being those three measures possible indicators of learning outcomes.

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After having elicited the usability "macro-requirement" in a set of requirements for all design scales, from urban area to technical components and devices, markers and indicators for each of them have been defined, as well as criteria for usability assessment of existing or planned buildings. Finally, a change in primary school design processes is proposed, introducing human factors consideration as key design variable.

2.2. Research development

The whole methodology was formulated and tested within a case study, given the need to collect data about activities and users.

Delivered methodology is based on steps listed below:

- survey of primary school users;
- activities overview and task analysis of pupils and teachers activities;
- formulation of usability requirements needed at the urban, building, room and device scale for each activities area;
- elicitation of at least one marker for each usability requirement, for all considered scales;
- elicitation of at least one indicator for each usability requirement with related technical specification;
- formulation of a questionnaire for users satisfaction measurement to be applied in case of existing buildings
- setting-up of a matrix for a compared reading of all gathered measures, in order to assess the global usability level of school environment and prioritize design specific goals experimentation of the method in a primary school case study.

The range of acceptable values for each indicator was defined in order to assess built environment compliance to usability requirements either in existing schools, either in planned buildings through an *ex ante* assessment.

2.2.1. Primary school users

Users of school buildings belongs to many different categories, with different goals and experience in building use [3]. In fact, other than variously aged pupils and teachers, daily users include also management and facility staff or, for what concerns sur-

rounding areas, accompanying parents. As occasional users can be considered parents entering the building for stance to meet teachers or take part to school social events, but also anyone from community using facilities (i.e. gym or theater) in case of community-oriented management, as generally desirable [5], [8].

Given the focus on the role of buildings in learning outcomes, task analysis was conducted for the two main user clusters, children and teachers. Despite that, during the requirements elicitation step, a general attention was paid also to spatial characteristics matching needs of occasional users, especially for what concerns community use of school buildings.

2.2.2. Primary school activities and task analysis

Given the duration, the rather great number of tasks and involved people, before conducting a task analysis a general survey of the type of tasks carried out in a primary school was done. Therefore, several activity types were defined; these are not based on a specific education model (e.g. public Italian primary schools rather than Montessori, Steiner approaches, etc.) but are intended to be suitable for any educational system. Hereafter the activities successively investigated by mean of task analysis:

- school- context transition
- theoretical teaching
- experimental teaching
- artistic and gymnastic activities
- health and hygiene activities (including alimentation)
- management
- didactics preparation
- school-family integration/cooperation
- auxiliary activities (maintenance and cleaning, children supervision, etc.)

Task analysis was carried out breaking down activities and describing them following the chart in Figure 1; it was conducted separately for children and teachers.

This detailed task analysis was a relevant source of information about characteristics of building and urban surroundings able to obstruct or support the effective, efficient and satisfactory accomplishment of school users tasks.

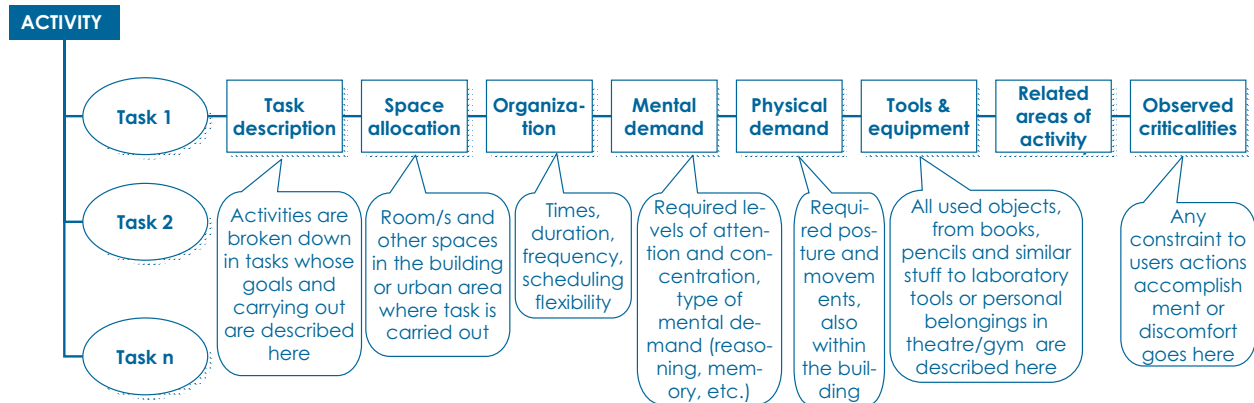


Figure 1: Contents of task analysis carried out for activities executed by children and teachers.

2.2.3. Primary schools usability requirements, markers and indicators

On the basis of a wide literature review (e.g. [7], [12], [1], [8], [10], [3], [19], [19], [21]), and data gathered with the above described task analysis, a set of usability requirements for urban context, school building, rooms and, finally, architectural technical components and furniture were formulated, as listed below:

a) usability requirements for urban context

- users safety
 - pedestrian and vehicular accessibility
 - area healthiness
 - affective dimension
 - building-context physical transition
 - building-context functional connection
- #### b) usability requirements for building
- protection from intrusions
 - control of users flow
 - flexible allocation of functions/activities/tasks
 - compatibility with multiple pedagogical approaches
 - adequacy of functional facilities
 - path efficiency
 - orientation
 - wayfinding
 - multiple levels of privacy/socialization
 - smooth transition from outside to inside spaces
 - acoustic comfort
 - thermal comfort
 - integration among school functions and other social functions

- overall aesthetic (pleasantness)

c) usability requirements for rooms

- visual comfort
- thermal comfort
- smell and breathing comfort
- inside-outside direct connection
- classroom-common space connection
- dimension proportionate to users number (crowding)
- layout customization
- privacy/socialization controlled levels
- cleanliness
- outside views
- void spaces clear transit

d) usability requirements for architectural details and furniture

- user safety
- noise proofing
- posture comfort
- customizable finishes
- regulation devices reach ability
- easy to clean.

In order to deliver a practical tool for usability assessment, suitable to support design or refurbishment decisions, requirements defined under a general perspective were matched with the specific activities to which they are relevant. In this way, usability assessment would provide the actual level of building supportiveness to each activity, fostering a design prioritization based on resulting poorest activities.

A common, basic, requirements for all scale is an implicit one, that is the compliance to all regulations concerning HSE, accessibility and minimum facilities. This is not properly an usability requirement, but

it encompasses many requirements from applicable laws and standards that, in their whole, represent a sort of minimum building usability entry level.

Aiming at shifting the school usability assessment towards quantitative, rather than qualitative judgment, a further elicitation of requirements was done. This more detailed stage of the study produced usability one or more markers and indicators with their related technical specification for each requirement [12]. Totally, 198 markers (46 for urban context, 72 for school building, 35 for rooms, 45 for architectural details and furniture) and 246 indicators (respective-

ly 98, 76, 72 and 46) were formulated. Finally for each indicator a technical specification was expressed, when applicable, with a numerical value and, in all the other cases, with a yes/no option.

It has to be observed that delivered markers and indicators do not represent a closed list, since new indicators and markers can be created to better take into account the specific school to be analyzed (e.g. the presence of bicycle path may be very relevant in case of lowlands, but it could make no sense in case of great distances or mountain/hill towns).

Table 1

Sample of requirements elicitation at different scales.

	USABILITY REQUIREMENT	MARKERS	INDICATORS	TECHNICAL SPECIFICATIONS
Urban context	Pedestrian and vehicular accessibility	Weather protection	Sheltered connection between parking and building entrance	Existing
			Sheltered connection between bus stop and building entrance	Existing
	Affective dimension	Support of social interaction	Square or widening with street furniture	Distance < 200 meters
			Porches	Distance < 200 m
			Gardens/parks	Distance < 200 m
			Steps / low walls	Distance < 200 m
Order and care	Order and care	Façade maintenance status	Absence of visible decay or alterations within 200 m	
		Street maintenance status	Trash collection points distance > 200 m Absence of visible decay of streets and street furniture within 200m	
Building	Wayfinding	Implicit environmental signs	Lightening type	Use of differentiated type of lightening for different activities/rooms (e.g. different Lux quantity/Kelvin degrees/natural rather than artificial, ...)
			Furniture and architectural finishes colors and/or materials	Use of different colors/materials for different activities/rooms
			Windows allocation on façades	Nearby buildings or other school wings are visible from walkways
Rooms	Outside view	Nature view	Sky view	Height of transparent surfaces from floor < 0.8m Sky visible from any bench/workstation
			Green areas view	Height of transparent surfaces from floor < 0.8m Green areas visible from any bench/workstation

2.2.4. Questionnaire for users satisfaction measurement

According the usability perspective, questionnaires addressed to school users were aimed at understanding their appreciation towards the way of tasks accomplishing as well as the easiness of goals achievement [15], [21]. In the framework of this rather general meaning of satisfaction, questions were tuned in order to gather satisfaction data related to one or more technical factors. Therefore, aside from personal feelings about some aspect of school climate and individual preferences, questionnaires items were specifically addressed to satisfaction aspects concerning markers and/or indicators previously defined for usability requirements.

Two different questionnaires were formulated for children and teachers; pupils version contains 65 questions, whilst teacher one is made-up by 78 questions, with a 4-level Likert scale for answers. The even number choice for answers came from the need to avoid neutral answers, prompting experimental subjects to critically express their feelings rather than considering as good the everyday situations they are accustomed to.

The chosen approach to satisfaction measurement provided a twofold benefit: first one is related to the possibility to highlight most sensitive technical aspects (at all considered scales) that need to be considered in case of architectural project aimed at improving school usability, as depicted in Figure 2.

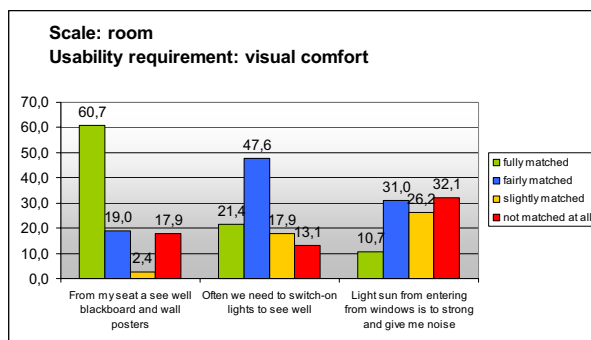


Figure 2: Sample of pupils satisfaction measurement (questions n. 50, 56 and 57) crossed with usability requirements, expressed as percentage of agreement with statement.

The second one concerned the research development, since users direct involvement allowed to check if set-up indicators were relevant and technical specification value significant under the learning outcomes perspective, realizing a sort of validation step

of the whole requirements/technical specification framework released.

3. Results from methodology application in the case study

3.1. The case study

Case study concerns a primary school building located in Naples city centre. The “Principe di Napoli” school is a 5 floors building, laying on an urban area of 755 m², with a 68 m² outdoor area and a total amount of internal surfaces of 2865 m². Beside from a primary school, building hosts a kindergarten and a middle school. Primary school had, at the time of the investigation, 446 pupils in 23 classes, 42 teachers, 23 persons as accounting department and auxiliary staff.

Users panel participating to satisfaction measurement was a group of 87 pupils and 8 teachers, that were children and their teachers involved in third, fourth and fifth grade of C and D school sections.

3.2. Usability assessment of “Principe di Napoli” school

The proper usability assessment was carried out in two steps. First one consisted of data gathering for the three effectiveness, efficiency and satisfaction measurements.

Compliance with applicable national and local regulations was considered as measure of effectiveness, since school buildings couldn't operate under non-compliance conditions and, consequently, education could not be provided at all.

Also efficiency is an objective measure, given by the ratio among achieved goals (that is education) and spent resources. In this case, data gathering for measurement was aimed at surveying any feature of urban context and building potentially representing an obstacle in carrying out learning/teaching activities. In fact such a kind of obstacle is a sign of “not supportiveness” of the school, since it demands additional efforts to gain expected goals or, alternatively, to reduce the extent of goals achievement. Thus, being usability requirements based on a detailed task analysis and formulated as the set of built environment characteristics able to support users tasks, efficiency was measured checking the built environment compliance to markers and indicators formulated for each usability requirement. With this aim, a checklist was

prepared for urban context, building, rooms and architectural details survey.

For what concerns satisfaction, questionnaires were submitted and collected after a week; answers were stored in a database and statistics represented with charts.

At last, in order to proceed with the overall, final, usability assessment, a matrix was framed aimed at collecting and comparing results of singularly evaluated measures. In that way, a single row showed if an usability requirement and its markers were matched by related aspects mentioned in regulations, actual built environment conditions surveyed in the field and users personal feeling. In a conclusive column the usability assessment was formulated according criteria in Table 2.

User satisfaction is considered fulfilled only in case of more than 75% of pupils and more than 75% of teachers have considered fully or fairly matched

the investigated requirement/marker. In some cases, especially at urban and detailing scales regulations do not provide applicable references and the correspondent effectiveness box was left blank.

Table 2
Criteria for overall usability assessment.

		KEY
All related indicators are matched	Usability requirement is fully achieved	
Regulation indicators + efficiency or satisfaction are matched	Usability is partially critical	
Any other case	Usability is critical	

Table 3

Part of the usability assessment matrix filled for "Principe di Napoli" primary school (see key in Table 2)

	Usability requirement	Markers	Indicators	Effective-ness	Efficiency	Satisfaction		USABILITY
						pupils	teachers	
Urban context	Pedestrian and vehicular accessibility	Weather protection	Sheltered connection between parking and building entrance	✓	✗	✓	✗	
			Sheltered connection between bus stop and building entrance	✓	✗	✓	✗	
	Affective dimension	Support of social interaction	Square or widening with street furniture	N.A.	✗	✗	✗	
			Porches	N.A.	✓	✓	✓	
			Gardens/parks	N.A.	✗	✗	✗	
		Order and care	Steps / low walls	N.A.	✗	✗	✗	
			Façade maintenance status	N.A.	✓	✓	✗	
			Street maintenance status	a) N.A.	✓	✓	✓	
			b) N.A.	✗	✓	✓		
Building	Wayfinding	Implicit environmental signs	Lightening type	✓	✗	✓	✓	
			Furniture and architectural finishes colors and/or materials	N.A.	✗	✗	✗	
			Windows allocation on façades	✓	✓	✓	✓	
Rooms	Outside view	Nature view	Sky view	a) ✓	✗	N.A.	✓	
				b) ✓	N.A.	✓	✓	
			Green areas view	a) ✓	✗	N.A.	✓	
				b) ✓	N.A.	✗	✓	

4. Discussion

This paper has presented a methodology for school usability assessment and design, aimed at providing architects with data and tools for the design or the assessment of usability requirements, so that outcomes of educational efforts can be maximized by built environment features.

The main output of the study is a framework of usability requirements, markers, indicators (and technical specification to be applied in usable primary schools design and assessment.

Main outcomes achieved are:

- the verification of relationships between performances assured by the fulfillment of laws and standards request and actual holistic performances provided by buildings, under the perspective of their adequacy to users' activities;
- a rather wide scale trial in the field of the possibility to turn implicit users' needs into technical requirements and specifications, objectively measurable.

For what concerns first point, it has been observed that learning activities, especially under the user satisfaction point of view, are only relatively affected by building fully compliance with Italian regulations. On the contrary many of relevant characteristics are out of the regulatory field; inadequacies relates mainly big scale (urban context) and detail scale (technical devices, finishes, furniture).

In relation to the second outcome, two main consideration can be drawn. First one is about the relevance of urban context quality for efficiency and users satisfaction, the other one is that technical specification coming from implicit needs of users have been validated, in their majority. Therefore, one of most relevant aspect of this research is the translation of users' expectations (qualities of built environment) into technical specifications (quantities for built environment detailing).

Referring to usability principles, perceptive and organizational aspects have been included in analysis and assessment of primary school; this allowed the consideration of intangible qualities in existing buildings highlighting some underestimated resources, which otherwise would have not been understandable.

On the other hand, the application of this usability methodology helps to sketch multiple scenarios, enhancing the iterative design process and the comparison of alternative design plans. Then, the proposed approach represents a decision support for a better use of financial resources for school buildings, since

architectural interventions can be conducted balancing *soft* and *hard* facts constituting the learning context of use [21], [8], [18].

Finally, the awareness about usability performances offered by built environment provides data for prioritization of buildings management and maintenance as well as for the best possible arrangement of learning activities scheduling and layout.

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