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RESEARCH ARTICLE

EDUCATIONAL PROCESS OF TEACHING COMPUTER AIDED DESIGN: FAMILIARIZATION OF NOVICE STUDENTS WITH TECHNIQUES OF DIGITAL ARCHITECTURAL/URBAN/PLANNING DESIGN AND INTERACTIVE SIMULATION OF A BUILT-UP AREA.

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Abstract

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Object: This research refers to the teaching of computer aided architectural/urban design and presents an educational process/method of digital design/simulation of architectural and urban space via computer aided design systems. This educational process was applied in tertiary education in two faculties of engineering of European universities and was taught to engineering students who studied architectural/urban/regional spatial planning.
Methods: The phases of this educational process broadly (a) identify needs in the framework of teaching digital design and (b) define pedagogical thematic entities and their contents in the form of lesson plans (defining a study area, students' roles and groups, and describing partial, short-term and long-term research objectives). This educational process was evaluated by (a) a questionnaire on digital design influence on students' learning, understanding and practice and (b) a students' grade results analysis of digital design courses.
Results: 68% of the students indicated the 'learning and adapting digital design process' as a normal to easy process and almost 80% that digital design helps 2D/3D spatial perception. Only 39% of the students indicate that digital design helps significantly the design conception process (lack of digital design integration in conception process). Furthermore, the learning performance of the university students (higher academic level) proved more significant than that of those who attended technological educational institutes (lower academic level).
Conclusions: The digital design process necessitates a clearly engineering reflection. On the other hand, the engineer must 'protect' and 'adjust' their critical approach and conception process to the demands of digital design methodologies.

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Introduction:-

In the context of the of 1st and 2nd year courses, 250 engineering students of two different engineering departments of European universities: (a) School of Spatial Planning and Development, University of Thessaloniki, Greece and (b) Department of Civil Engineering, Educational Institute of Thessaly, Greece, during three academic years, were introduced to computer aided architectural and urban design and an educational methodology has been applied and developed. The specific course, which involves theory and practice, was taught as an introduction and followed the

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courses of Informatics and Design in the 1st and 2nd year courses. The basic aim of this educational process, from a pedagogical point of view, was not only to define Pedagogical Thematic Entities (PTEs) and their lesson plans but also to apply a methodology through practical tasks.

The purpose of this educational process, from a practical point of view, was to familiarize students with innovative techniques and tools of digital design creation in relation with comprehension of basic theoretical concepts of computer aided architectural and urban design and simulation. The further goals of this process application were to:

1. make students aware of the adaptation of 'digital conception' into the architectural conception process with a critical approach in order to avoid a 'blind' use and application of this knowledge;
2. make students actively participate in a methodological, educational and productive process;
3. introduce the students into the research process.

The educational process was developed multi-dimensionally in three equally important, related PTEs with their lesson plans in the context of a theoretical and practical approach to digital design teaching in 10-12 sessions during the semester. The first PTE concerns the theoretical approach and analysis of a complete system of digital architectural and urban design with related parameters. The second PTE concerns a practical application of basic theoretical concepts through modeling preparation, presentation and familiarization to adequate software. The third PTE concerns the final modeling and simulation of architectural and urban space via application of adequate software (Fig. 1).

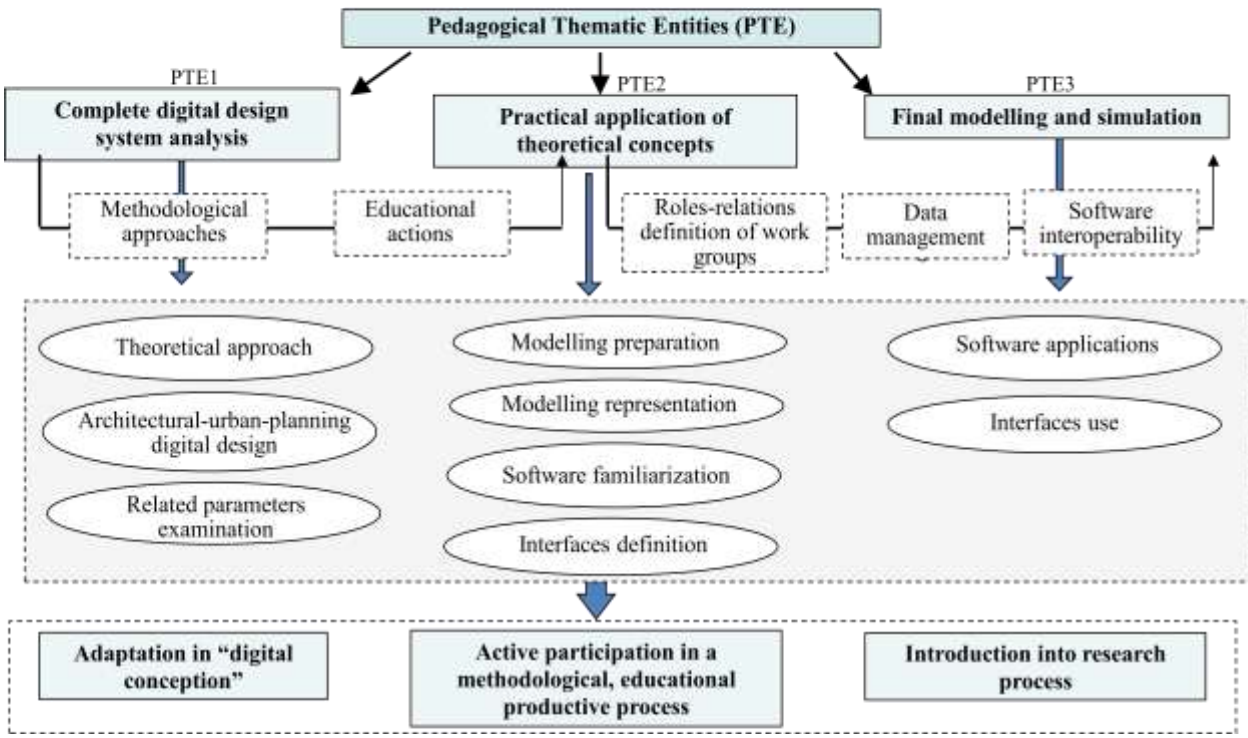

Fig 1:-Schematic presentation of pedagogical thematic entities of the educational process of 'computer aided architectural urban design and simulation' teaching

Methodological approaches and educational actions frame the PTEs and correlate to the definition of the study area, the students' work groups, the roles and the relations between work groups and corresponding parts of the study area, the data management, the interoperability of different pieces of software used, etc.

Teaching Digital design:-

Concepts and reflections

Teaching digital design should be connected to an approach of teaching spatial thinking and specific techniques in order to develop spatial skills in design education. Spatial thinking is a collection of cognitive skills consisting of declarative and perceptual forms of knowledge and some cognitive operations that can be used to operate on, combine, or transform this knowledge (NRC, 2006). The conventional approach to teaching spatial skill development in engineering design graphics relies upon the introduction of concepts, sketching, 3D modeling, orthographic projection, pictorial drawings, and geometry (Mohler, 2007). The development of spatial skills and abilities within the context of 3D digital environments is very important. Enhancing the ability of students to think spatially and communicate visually in analog and computational design environments, will equip them with the abilities of problem solving and skills processing which are required in new and emerging design contexts (Youssef and Berry, 2011).

Innovative learning designs that incorporate advanced technologies, such as instructing on solid modeling (Sorby, 2009; McLaren, 2008), mentored sketching, animations and computer games focusing on manipulation of objects (Mohler and Miller, 2008), etc., show positive results in supporting students' acquisition of spatial skills within these contexts (Park *et al.* 2010).

Teaching digital design can be closely related to Design-based learning (DBL) in higher engineering education contexts because the DBL characteristics which are the project's characteristics, the role of the teacher, the assessment methods, and the social context (Gomez Puente *et al.* 2012) are also very important issues for teaching digital design. Additionally, when computer aided design (CAD) teaching, which is an essential part of digital design teaching, is targeted, it produces a significant improvement in the spatial ability of students and thus provides the most significant benefits for the training time committed (Onyancha *et al*., 2009).

It is necessary to investigate the concepts of how to learn, where to learn and what to learn in order to teach students the design process (Ataman, 1995). According to the first issue, of how to learn, the classical pedagogical approach emphasizes correct performance but recent cognitive theories reject this approach by focusing on the process instead of the product (Lochhead, 1979). According to the second issue, of where to learn, the classical approach supports that skills learned in one area can be used in different areas but other studies maintain that knowledge learned in one area can be successfully used mainly in that area. The third issue, of what to learn, indicates that students need to appropriate concepts in a quite comprehensive way so that they (a) appreciate their usefulness, and (b) learn how to use that knowledge in design. Concerning the description of software that we need for instruction and Computer Aided Architectural Design (CAAD) teaching, many needs and features have been proposed. These needs are related to a user friendly interface, cross platform compatibility (continuity in the use of software in both school and professional practice), programming and macro language presence, full DDE and OLE support (by permitting the data dynamic exchange support, graphic entities, data field, etc), and extended network support (workgroup activities and collaborative design, extended functions and data information in Internet, etc) (Scianna, 1996).

Due to recent theories, a correct teaching of digital design is based on several assumptions (Bailey, 2005). Firstly, the educational structure must relate to the structure of design problems in order to be useful to the design process and teach students about the issues involved in design. Secondly, basic knowledge must contain the kinds of clues that ground the student in the realities of design. What is more, the use of computer as a teaching tool must be consistent with theories related to computer assisted teaching and learning. Finally, design learning is personal; therefore, learning methods must be included in the learning advantages of the tool.

Didactic methods try to integrate analog and digital tools into architectural and urban design education. In a first phase, students must learn to perform many tasks, from simple freehand sketches up to modeling complex 3D-structures and in a second phase, which is dedicated to the design process, students should be prepared to develop and present their own digital ideas by handling, in a sufficient way, tools of digital design (Stavric et al., 2007).

Computers and users can be knowledge instructors on collaborative design environments by following design process methods. These environments provide users tools for posting knowledge productions into a shared working space and provoke progressive discourse interaction between the users (Scardamalia and Bereiter, 1994). New generation networked learning environments facilitate collaborative designing by sharing the design process and involving intentionally treating elements of inquiry such as problems, design ideas and processes, tentative solutions – as objects of knowledge on a network database where students have access (Seitamaa-Hakkarainen et al., 2001).

Other pedagogical proposals: Related approaches

First-year university students of an interdisciplinary course called Spatial Thinking and Communicating (TECH 106), which is part of a TechOne Program (a first-year interdisciplinary program at Simon Fraser University of

Canada) are introduced among others to problems requiring spatial thinking such as examining and interpreting 3D representations, visualizing and defining spatial problems and proposed solutions, creating and manipulating 2D and 3D representations, selecting representation tools and techniques and using a computational modeling tool (Youssef and Berry, 2011). The design course is composed of four elements during the educational semester:

1. Direct instruction and guided practice of foundational concepts and skills (projection planes, principal views, objects visibility, 3D visualizations, etc);
2. Student preparation with a familiar and simplified version of a ‘‘fun’’ computational design tool (LEGO objects use, gimbal system components, gimbal visualization and sketch, zoom, object functionality and structure understanding from its concept map, etc);
3. Introduction to industrial-strength computational design software (aspects and assembly features of SolidWorks, base features and sketches creation and definition by using a 2D sketching and dimensioning tool, 3D parts modelling using an adequate feature tool, geometrical relations, animations, textures, etc);
4. Team-based design project using SolidWorks (materials, gravity forces, dimensions, physical and digital model relations, modeling additional motions, sketching strategy, etc),
   (Youssef and Berry, 2011).

Multi-level pedagogical schemes introduce associative geometry and parametric modeling/design into architectural and urban digital design education. One of them is based on pedagogical experiences of a spatial geometry course in the first year of education and also in a digital design studio with third-year students. It discusses the impact on design exploration of a library of interactive referent models with paradigms of digital design methods based on modification of meaningful features (structural, environmental, functional, etc.). Thus, the form of a design object can 'follow' function, structure, or even sustainability (Iordanova, 2007).

Another study offers a theoretical framework for teaching digital design based on the concept of computable functions. It presents computable functions and levels of design computability such as “representational”, “parametric” and “algorithmic” which involve Oxman’s digital design models (Oxman, 2008) such as CAD models, formation and performance models, and generative models. This enables a grouping of contemporary digital design methods and an understanding of their logical relationship in order to open a path for the study of a mechanism that facilitates transfer of concepts from various scientific disciplines into digital architectural design (Kotnik, 2010).

Other didactic processes are based on different kinds of models (such as CAD, formation, generative and performance models). According to Zaero-Polo (2001), processes are becoming far more interesting than ideas. Processes of generation are synthesized as a kind of accelerated motion adding information integrally to the construction (Zaero-Polo, 2001). Thus, the concept of digital formation models is becoming a medium of conceptualization; animation and parametric design are two digital techniques associated with formation model. Generative models of digital design are characterized by provision of computational mechanisms of generative processes and performance-based models are driven by simulations (Oxman, 2008) and this approach can generate and modify designs digitally (Oxman et al., 2007). The didactic process consists of the following four basic steps:

1. Conceptualizing and defining a specific type of ‘digital material’. Digital material can be defined as an organizational structure, or pattern, of a certain material;
2. Defining a specific digital design model related to formation, generation, or performance, or relationships of such models;
3. Selecting a context that can best demonstrate the behavior and applicability of the ‘design material’ in relation to principles related to formation, generation or performance;
4. Developing and presenting a taxonomy (related to digital architecture) that can be used to describe the digital architectural design thinking processes.
   (Oxman, 2008)

Pedagogical thematic entities (PTEs) and lesson plans:-

An implementation of a “design-oriented programme” was proposed, according to recent theories (Silva, 2000), as a ‘complete’ programme structure for students to be able to handle different aspects of digital design. This programme contributes to avoidance of serialization of the design process which might have been caused by a teaching programme with well-defined courses.

The first part of this design-oriented programme is dedicated to the introduction of basic skills and theoretical background such as 'introduction to computing', 'introduction to computer-aided design' and 'design theory and computers'. The second one is dedicated to the development of a design project with integration of computer techniques. Finally, the third one is dedicated to advanced topics, for instance 'Introduction to Software Engineering and Programming', etc.

According to other theories, the main criterion of classifying different modules must be coherence of courses. Thus, two general sections could be made. The first section of the courses concentrates on technical computer issues concerning multimedia techniques, computer hardware and CAD-software. The second section focuses on architectural design concerning issues such as basic design concepts and design theories or methods. In general, these courses aim to achieve practical skills and technological insight, namely, the 'computer aided' aspects of CAAD (Van Zutphen et al., 1999).

The present educational process is composed of three, related to each other, PTEs. Each PTE includes theoretical and practical issues of digital design teaching which are grouped in lesson plans. The grouping of theoretical and practical issues in lesson plans is based on the thematic content and concerns neither the time nor the order of presentation. The PTEs and their lesson plans are the main means of familiarizing students without any previous adequate knowledge with the techniques of digital design during the educational process.

The first PTE concerns the theoretical approach and analysis of a global system of digital, architectural and urban design with related parameters. The objective of this thematic entity is basic and necessary theoretical knowledge of digital design in order that students critically proceed to any CAAD application process and understanding the problems, the limits and the capacities of this kind of operation. The content of this PTE is linked to the creation of adequate lesson plans concerning:
1. An introduction to the potential applications of CAAD systems including capabilities of modeling / simulation for architectural, planning and designing purposes;
2. The analysis and presentation of components of a digital design system describing the involved hardware (computer parts and peripherals, scanning, printing, variables, definitions - dot, pixel, dpi, ppi, etc) and related software (drivers, viewing / editing platforms, programming tools);
3. A review on terms and meanings related to data storage, manipulation and display: binary data, memory, ASCII format, color models (RGB, CMY, HSI);
4. The description of vector and raster methods for spatial data storage and manipulation explaining techniques for data input for each method (digitizing) demonstrating the advantages / disadvantages and the most common applications of each method and presenting widespread software related to both methods;
5. Description of devices and methods which are used to present and simulate a design via a digital design system (input, output, physical colors, chromatic models, memory, simulation), etc;
6. The use of coordinates in digital design systems (modeling environment) in relation to geographical and projection coordinates (real world) for simulation, designing and planning procedures;
7. Basic transformations, coordinates and related algorithms (translation, scale, and rotation), basic algorithms of digital design: window, view, clipping, hatching, hide, etc;
8. The use of layers for data management and discrimination of superimposed designs;
9. Introduction to the development of programming language environments (Visual LISP – Visual BASIC), basic knowledge, introduction to automation and function adaptation in special needs of the digital design, etc.

The second PTE relates to the preparation of the model and presentation and knowledge transfer of the adequate software. The objective of this thematic entity is the introduction to the rationale of preparation, conditions and creation of 3D objects based on existent 3D objects or from the very beginning. The adequate lesson plans of this thematic entity concern:
1. Knowledge transfer of CAD software (AutoCAD, Architectural Desktop, Sketch Up), basic and specific commands of 'draw' and 'modify' objects (draw – modify – 3D – blocks – files – import-export – interfaces, etc.);
2. Function of basic coordinates transformations (translation – scale – rotation – etc.);
3. The understanding of the digitizing process with transformation of an analog design or image into digital format via a computer aided design software;
4. Knowledge transfer of image processing software and interactive Internet application of architectural virtual simulation and urban models (Google Earth);

5. Dealing with interactivity problems between different adequate softwares and the re-establishment of the inter-functionality between the 2D design base and the 3D model.

The third PTE is pertinent to the final modeling and simulation of the architectural and urban space. The point of the thematic entity is the synergy of different applications of CAD, interactive virtual simulation, image processing, calculation and data base management software in order to reach the final modeling and simulation. Adequate lesson plans of this thematic entity concern:

1. 3D modeling entities based on previous adequate 2D objects preparation;
2. Exploitation and adaptation of satellite images and data relief of the study area into modeling and simulation environments;
3. Display of detailed, architectural, photographic material and its adjustment process into 3D model surfaces;
4. Final adjustment of the model in a virtual reality environment via specific interactive Internet simulation.

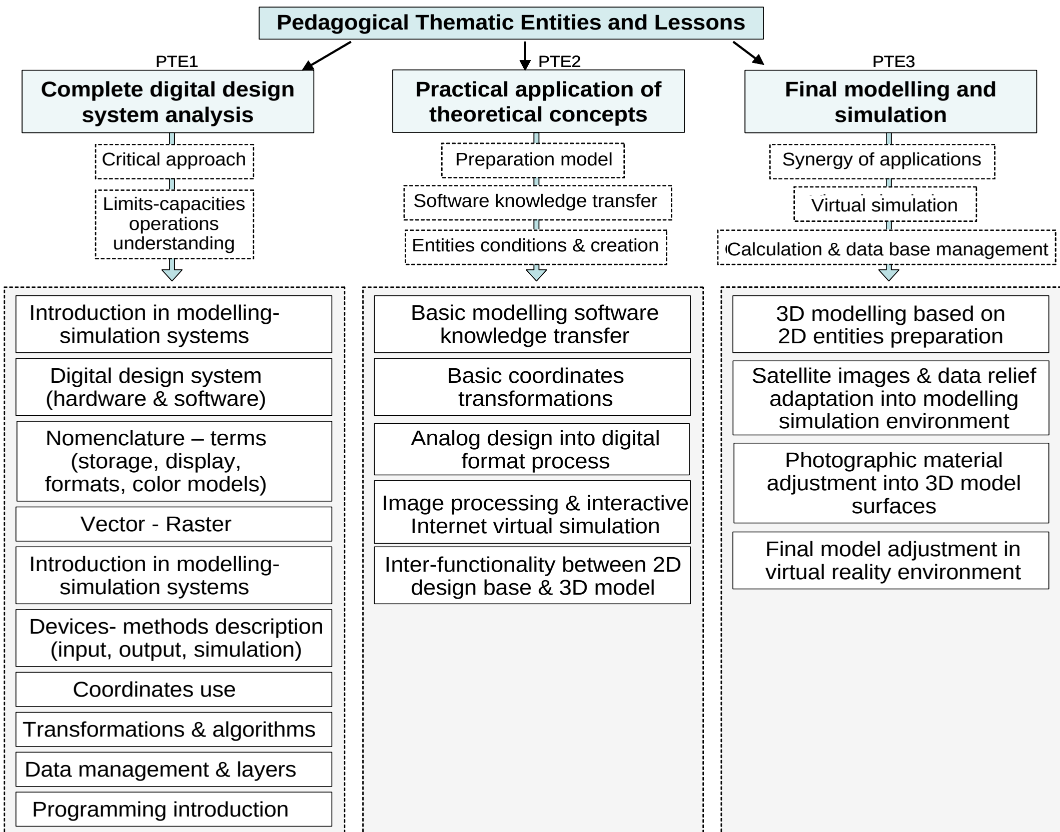

Fig 2: -Structure and contents of a theoretical and practical approach to the architectural and urban digital design and simulation educational process

Material:-

Hardware

The department operates a computer laboratory with twenty workstations running Windows 10 and one server running Windows Server 2010. An overhead projector and a laptop computer are available for trainers in the classroom. Two network printers (a LaserJet and an inkjet one) are shared through the local network and a scanner (A0) is connected to a workstation. The workstations of the laboratory have a permanent connection to the Internet through the server (gateway). Additionally, a digital camera (15 MPixel) is available to students.

Considering that forty students participated in the course and the computer laboratory operates twenty computers, a basic issue appeared to be the distribution of students to the available hardware. A further point is, that most students own a personal computer and the laboratory is open and available to them during all working days. Therefore, part of the workouts was performed after the course had finished (at the laboratory or at home).

Software

In the framework of this educational process, computer tools, as they are used in architectural practice today ("professional systems"), or computer tools, which any engineering student should be able to use ("social systems"), were used. This "Off-the-shell" software (social systems and professional systems developed by regular software houses) provides basic knowledge of design systems and experience of the use of CAAD or CAD systems in practice (Achten, 1996).

On all the workstations, AutoCAD Architecture, 3D studio max, Google Earth and Google SketchUp were installed. Microsoft's Photo Editor was available (from the running operation system). Additionally, IrfanView was provided as alternative free software for image processing and Photoshop for further image processing. Microsoft's Excel was used for data management and calculation via specific developing functions (data classification, images' dimensions adjustment, etc). Selection of AutoCAD was based on the fact that it is a well-known CAD platform (available in the specific educational institution) and a suitable tool which is supported by programming languages. Google Earth and Google Sketchup are both freeware items. The former provides geographic scenery for site-specific presentations with capabilities of virtual (3D) navigation, whereas the latter is easy sketching software with impressive finishing which collaborates with Google Earth for the geographic reference of 3D models.

Study area

As an experimental field, a central area of an urban space was selected, with a relatively smooth relief next to the everyday living place of the participant students. The urban space provides a geographic background for designing in small (e.g. for urban planning) and great (e.g. for architectural details) engineering scales.

Data

1. The available data for every phase of the methodology ('workout') was:
2. A topographic diagram of the wider area representing the parcels and the properties of the building blocks;
3. High resolution imagery and digital terrain model (DTM) through a utility of SketchUp software.

During the courses, the participant students had to walk around the study area and collect additional data such as:

1. The number of floors (for the estimation of total height) for each building;
2. The facade color of the buildings;
3. Photographic material for selected facades (with architectural details).

Methodology:-

The digital world differs from the natural world; it is very important for a teacher to show those differences in an explicit and systematic way in order to render the digital world intelligible to students and adjust his/her physical world habits with the different characteristics and behaviours of the digital world. To accomplish this step, a combination of theoretical issues and practice is necessary. Each concept must be isolated for study and practice by making a precisely constructed educational experiment that allows the student to perceive the referents of the concept directly (Talbott, 2003).

The course aims at the development of students' technical skills in creating a design in a modeling and simulation environment and their familiarization with theoretical matters and terms that are related with computer aided architectural design. The methodological approach for the teaching of the course of digital design and CAAD was presented previously and it is permanently related with every workout. Thus, every practical issue of the methodology in 'workout format', which is described further below, is based on previously presented theoretical issues. For this reason, the practical issues are basically the following:

1. insertion of the topographic map of the study area (as satellite image format) in CAD environment,
2. 2D digitalization of the study area in CAD environment (AutoCAD),
3. adjustment (transformations of translation, scale and rotation) of the 2D vectoring environment and the satellite imagery to the real dimensions and geographical position,
4. 3D modeling,
5. 'normals' surfaces management in CAD (AutoCAD) and rendering environment (3D studio max) so that the textures assignment and the 'double-faces' mapping could be realized without appearance problems,
6. adjustment of vectoring mesh relief (Digital Terrain Model) to satellite imagery with approximate accuracy,
7. adequate assignment (after merging, cropping, distortion) of image textures to buildings façades, and

8. interactive simulation – navigation in Internet or Virtual Reality environment of the complete 3D study area where virtual 3D models become ‘hyperentities’ (interactivity with links) (VR authoring software such as 3D studio max) (Fig. 3).

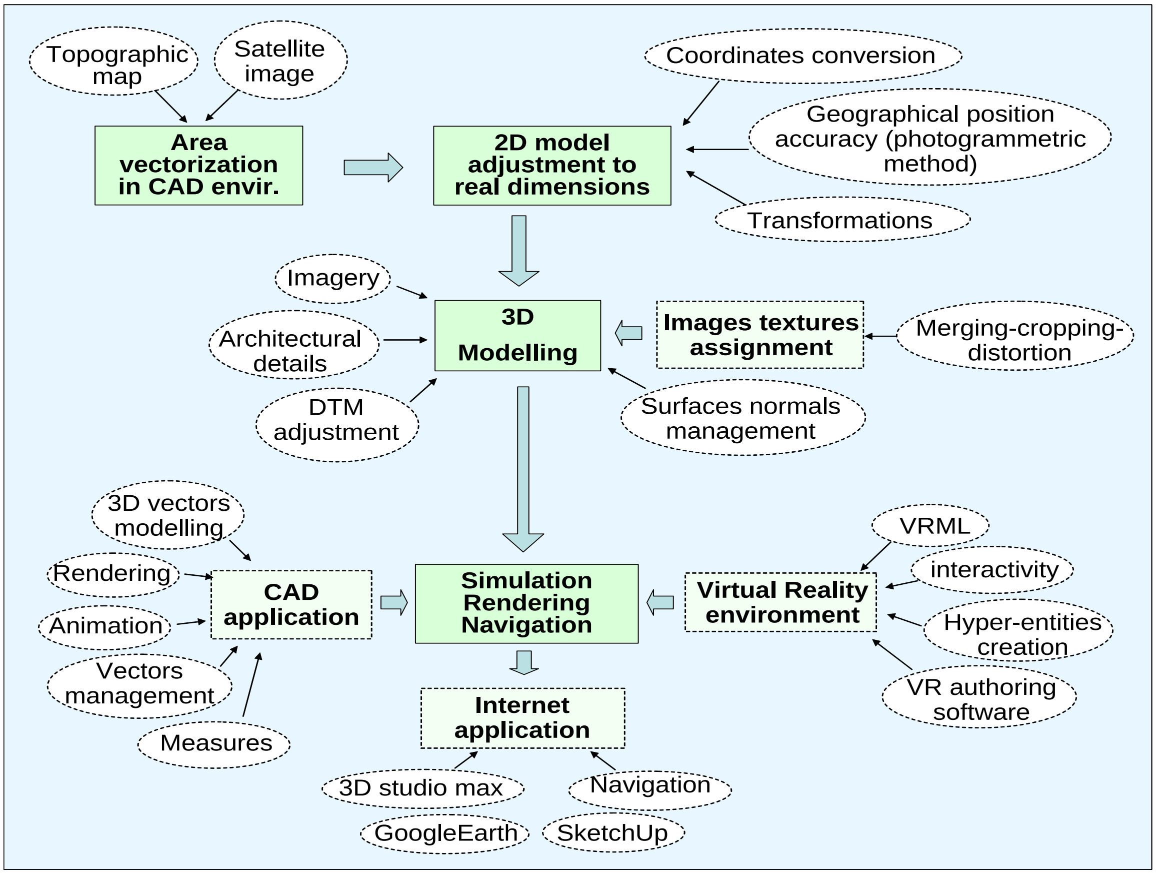

Fig 3: -Practical teaching approach scheme of digital design methodology

Workouts

A study area was divided into 16 sectors that correspond to 16 work teams. Each work team (2 to 4 students) performed four sequential workouts combined with specific educational tasks, as they are presented below. During the workouts, various pieces of software are used which provide tools and utilities related to the predefined pedagogical thematic entities and their lesson plans.

Digitization

The first educational task is the comprehension of digital design advantages (in relation to the analog one). This was achieved through digitization of the topographic diagram of the study area representing the parcels and the properties of the building blocks. The process is performed in two ways, initially, with the scanning of the original diagram (in various resolutions and color depths) and, sequentially, with the on-screen digitization (CAD environment) of the parcels of each team's sector. The resulting drawings from this task are used as a base layer for the next tasks.

This workout is combined with a prior theoretical introduction in raster and vector methods for data storage, as mentioned previously, and is accompanied by a demonstration of basic design tools in the environment of AutoCAD and Google SketchUp (lines/polylines, snaps, colors/styles) and layer stacking. The use of coordinate systems in CAD platforms (absolute /relative, Cartesian / polar) is also explained.

Data collection

Fieldwork has a double mission during the workouts; primarily, to give students the ability to establish a mental connection between the model (simulation environment) and reality (real world) and, secondly, to raise students' awareness of data collection matters for realistic representations that would be utilized later. A parallel educational task of this workout is to perceive limitations in modeling methods and the need for collecting adequate data.

In this workout, the students have to collect the number of the buildings floors in their sector. This number would be multiplied by 3.5 meters, considering this a common floor height in order to estimate the height of each building. The material and color for each building face were written down in order to be represented in the model. Furthermore, photos from selected faces with particular architectural details were taken to be used for photorealistic representations afterwards.

The workout is combined with theoretical topics concerning the formation of colors in peripheral devices such as screens (RGB color palette) or printers (CMYK color palette), their natural definition (HSI color palette) and memory for raster data storage or display depending on resolution and color depth.

3D Modeling

The modeling workout introduces the significance of coordinate systems, proceeds to the relation between geographic / projection and cartesian (modeling) coordinates, and explains the transformation algorithms. The study area is located in the Google Earth software and marked with the available tools (placemarks and polygons). Afterwards, the Google Earth tool from Google SketchUp software is used, to get the current view from Google Earth (obtaining the satellite imagery and the Digital Terrain Model (DTM) for each sector. The retrieved data is used as the geographic background to develop a 3D drawing. The digitized drawing from the first workout is imported and placed in accordance with the retrieved geographic background. The satellite imagery is used to digitize the buildings (inside each parcel). Every building is 'raised up' in 3D solid proportionally to its calculated height and painted in accordance with the collected data. DTM is used as the referencing level for the buildings' height. The result of this workout is the creation of an elementary 3D model describing the area of each sector. In this process, both raster and vector data are used. The workout is followed by the description of vector and raster methods for spatial representations demonstrating the advantages and disadvantages of each one and the use of layers to organize drawing data (background, model, details etc).

Facades

After the creation of the 3D model, the dimensions of the buildings' faces were calculated via a specific calculation function developed in Excel environment. The taken photos were edited using the Crop and Resize tools in order to comply with the faces' dimensions; photo editing was performed using the freeware IrfanView software. The editing of the further photo details was completed with Photoshop using Photomerge, Perspective Distort (Hartley, 1999) and crop techniques via special developed macro-commands with batch-actions. The edited photos were used as textures (respectively) on the facades of the 3D model (in Google SketchUp). This workout was based on the lesson plan concerning the raster data manipulation and display, describing an image's coordinate system and explaining the resizing process and the aspect ratio term for screens.

The increase of the image data volume handling such huge amounts of image data can generate many problems related to (a) dynamic referencing of the images, (b) sharing huge amounts of image data to an Internet application, and (c) decrease of volume of images by maintaining acceptable quality. This problem could be handled by adapting an image data archive system to the special needs of this procedure. According to an existing Image Data Archive System, image data can be referred dynamically and help to share huge amounts of image data via the Internet. This is feasible by an application developed with Internet language programming (HTML, XML, Flash, Action and Java Script). The major units of the "Image Data Organizer" and the "Image Data Browser" arrange the image data on the PC and permit the attachment of prepared keywords (Onishi et al., 2006).

Representation

The final step of the proposed methodology is the presentation of a summary of the workouts that was performed during the semester. This step combines results from all sectors in a common environment for 3D interactive navigation (Google Earth).

The use of the Internet interactive application (Google Earth) and the 3D studio max software improve the quality of architectural digital design training by extending the physical space of the architecture in an engineering laboratory into the virtual space of the network in order to achieve a real-time interaction (Architectural Virtual Space or AVS)

(Woo et al., 1996).

Each work team uploads its 3D model (using the "place model" tool from Google SketchUp) in Google Earth environment and shares it with other teams. The union of all sectors forms the 3D model of the study area. The purpose of this educational task is to understand the value of using a common coordinate system for referencing spatial data, especially in cases of collaborative efforts such as those that planners and designers participate in and to cope with data exchange (export / import) between different pieces of software. The presentation closes with a discussion on problems and their solutions during the described procedure. Afterwards, a review of the presented lesson plans during the semester follows, relating them to crucial points of the workouts.

The presented result, in addition to the result of the intermediate workouts, is part of the evaluation of the participants in the course of digital design. It is noteworthy that the evaluation of the results is not within the scope of this research article. It should be noted that the aim of this article is to define the educational process in question while the results of this process (presentation, simulation, etc) are the subject of future research.

Computational facilities

The novice students are introduced to and familiarized with computational techniques of basic programming languages during all the educational process. The choice of AutoCAD platform offers a programming support language in Visual LISP and Visual BASIC, which facilitate and automate digital design aspects such as 3D geodetic GPS coordinates conversion (φ, λ, h) in Cartesian coordinates (x, y, z), textures 'normals' management (visualization, orientation, inversion) and controlling bitmap dimensions in order to assign and adjust images textures to building facades (Kouzeleas, 2011). Additionally, the introduction to 'Photoshop actions' automates the textures distortion and images adequate adjustment to buildings surfaces.

Results:-

The described procedure results are in three submitted assignments, which are evaluated as part of the students' assessment in the course of digital design and CAAD:

Background Drawing

The first submitted assignment is an elementary 2D drawing of a particular sector (as it is defined for each work team). The drawing is the result of a topographic diagram digitization of the study area (Fig. 4) and contains two layers, one for the parcels and one for the building blocks.

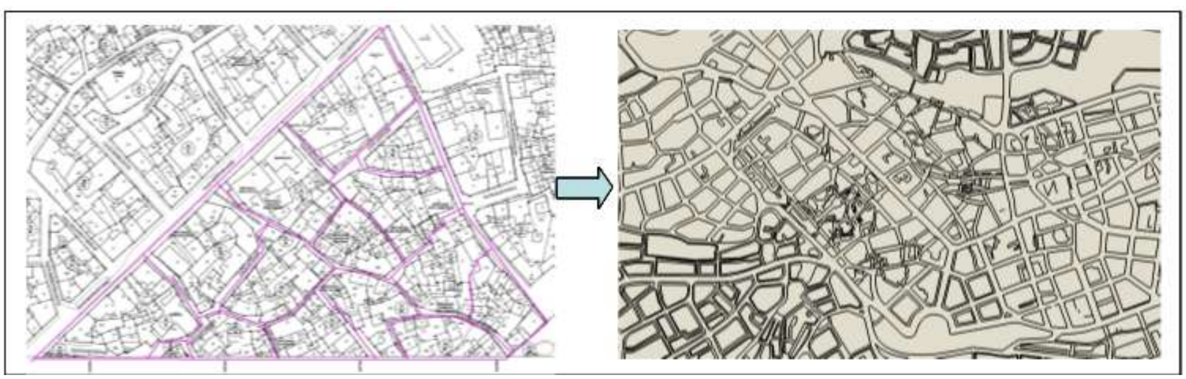

Fig 4: -The background drawing displays the parcels and the building blocks.

3D Model

The following submitted assignment is the creation of the 3D model of each sector. The buildings are digitized using the satellite image of the study area and their heights are calculated considering the height of each floor equal to 3.5 meters. The 3D model is built up over the previous background drawing. Images textures are assigned properly to building facades using developed actions in Photoshop based on merging, perspective distortion and cropping methods (Fig. 5)

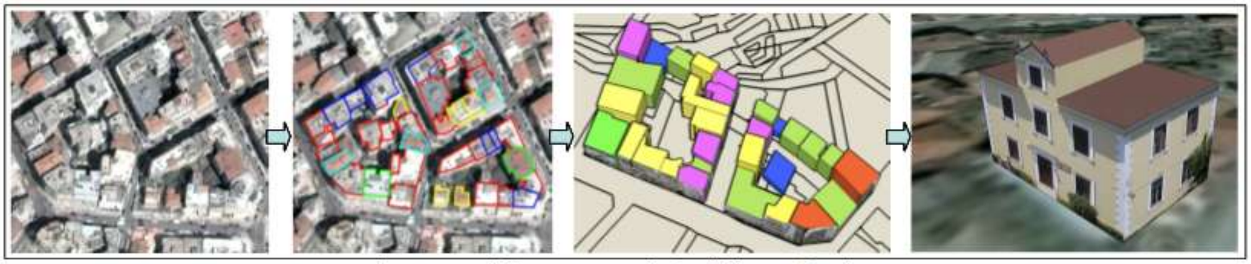

Fig 5: -The 3D model represents the buildings of a given sector

Virtual Navigation

This interactive simulation method allows students to review building concepts using three-dimensional visualization and interactive control. This method can be used as a method of learning which provides a vivid experience that could result in better understanding of digital design issues when compared to lectures or static images. However, this kind of example demonstrates some limitations of the technology (Alvarado and Maver, 1999). The model does not show geometric architectural details of the build-up area. It also requires explanations or schemes to clarify some concepts and it has to take under consideration proper pedagogical planning, guidance of experience and additional material which can be incorporated into a multimedia system. However, the examples show an important advantage of this technology which is the fact that 3D representations of technical and theoretical concepts facilitate an integrated view of architecture.\

The above architectural, urban digital design and spatial simulation tools are often used in digital cities cartography and contribute significantly in 2D and 3D spatial perception (Kouzeleas, 2012). The final result is a 3D model for the study area that is produced by merging the submitted assignments from all working teams (sectors). The model is uploaded in the Google Earth environment for virtual navigation (Fig. 6).

Fig 6: -The 3D models of the study area in a virtual navigation environment

Evaluation:-

Context and participants

The evaluation involves 250 students of two different university engineering departments during three academic years. During the three years in which the courses were held, (a) 40 novice (aged 18 to 24) students in the first year, 40 different ones in the second year, and 80 different ones in the third year of the polytechnic School of Spatial Planning and Development, University of Thessaloniki, Greece and (b) ninety (30/year for 3 years) students of the Department of Civil Engineering, Educational Institute of Thessaly, Greece, were introduced to architectural and urban digital design in theoretical and practical approaches. These students had no other previous work or teaching experience of digital design and methodology. For many of them the familiarization with new techniques of digital design was a strange and difficult process and the fact of sharing this experience in groups with other students helped them significantly to better understand, adapt to their needs and finally make an adequate use of this new technology. The majority of students started to express their positive impressions midway along the courses because of the more practical nature of the educational approach.

Approach

The evaluation of the educational process was oriented in two axes:

1. A questionnaire was assigned where students with the same small experience on both analog and digital design were asked to answer some targeted questions concerning the influence of digital design on their learning ability and practice;
2. The grade results of all students in these courses.

The questionnaire items were about digital design influence on four areas: (a) Learning digital design, (b) Spatial perception, (c) Reviewing and correction and (d) Design concept process:

Table 1:-Questionnaire on digital design influence

Questionnaire	
1	**Learning**
a	Difficulty to start learns and adapts digital design
2	**Spatian perception**
a	Help in 2D space perception
b	Help in 3D space perception
3	**Reviewing and correction**
a	Environment to review, correct & understanding
4	**Design concept process**
a	Help during the design concept

Results

68% of the students indicate that 'learning and adapting digital design' is a normal to easy process and 32% of them indicate that this is a difficult process. 78% to 87% of the students indicate that digital design helps 2D and 3D spatial perception, respectively. 63% of them indicate that the digital design environment is an adequate environment to review, correct, change and better understand architectural and urban space. Finally, only 39% of the students indicate that the digital design helps significantly the design conception process. This is justified by the fact that the students (a) were never introduced to digital design, and (b) never adjusted and used the digital design during their design conception process (Fig. 7).

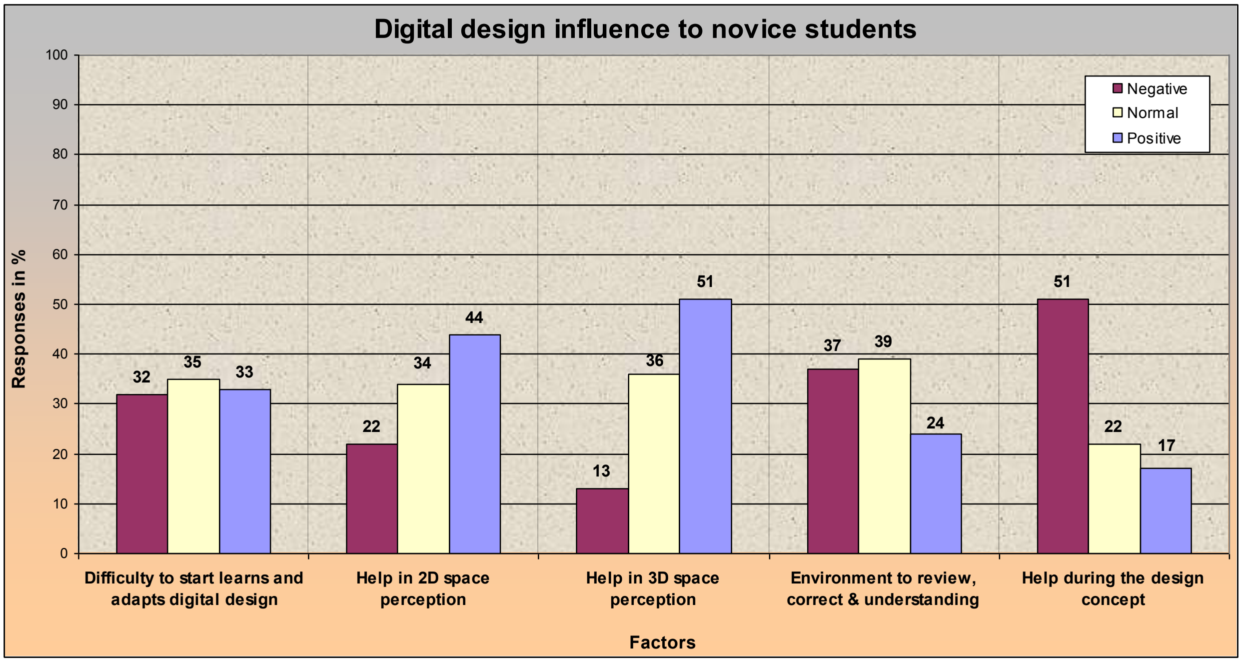

Fig 7:-Schematic representation of digital design influence on novice students

The grade results concern the average of the students' grades in the digital design courses of the two engineering departments during the 3 academic years (Table 2).

Table 2:-Average of students' grades in digital design courses

		1st year of research				2st year of research				3st year of research		
Technological Educational Institute		Bad	Good-very good	Excellent		Bad	Good-very good	Excellent		Bad	Good-very good	Excellent
	Theory	50	30	20	Theory	28	52	20	Theory	24	58	18
	Practice	42	38	20	Practice	29	45	26	Practice	17	60	23
University		Bad	Good-very good	Excellent		Bad	Good-very good	Excellent		Bad	Good-very good	Excellent
	Theory	24	55	21	Theory	25	55	20	Theory	26	59	15
	Practice	29	47	24	Practice	21	53	26	Practice	30	44	26

The results show that the grades in both educational institutes are better in practice than in theory; in the university the grades are higher than in the technological educational institute because of the higher academic level of the students and the more complete theoretical approach in their studies. These results encourage the goals of this educational digital design process and show that 71% of students in theoretical exams and 72% of them in practical exams passed the course. The student performance is more significant in the case of students of higher academic level (Fig. 8).

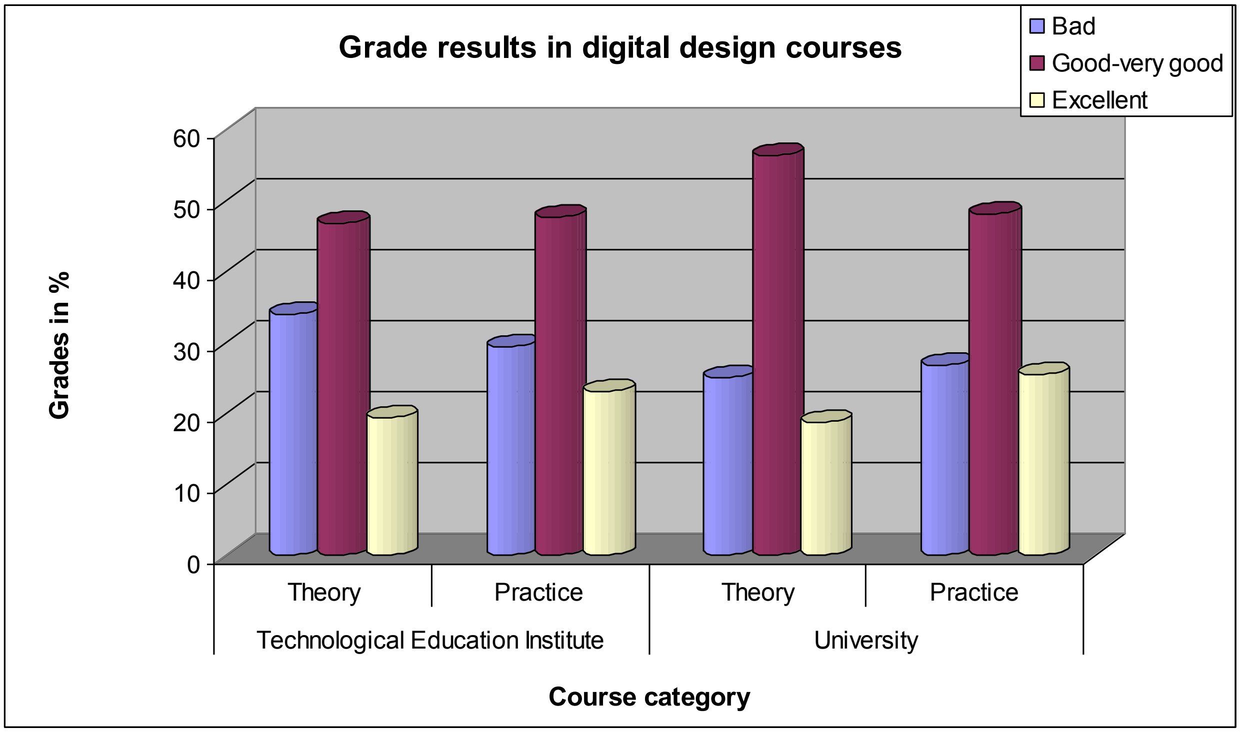

Fig 8:-Grade average results in digital design courses

Analysis and Discussion:-

The instructional challenge was to teach and familiarize novice engineering students with techniques of digital architectural and urban planning design in order to achieve the basic intended theoretical background and to integrate and apply all theoretical issues in an ambitious laboratory practical project. A detailed instructional framework was created in order to explore particular aspects of each element contributing to and posing significant challenges for students in order to achieve the intended learning outcomes. During 15 weeks, the students had the opportunity to collaborate with teams and follow authentic tasks within a complex computational design context (Lombardi, 2007) and a rigorous and well organized project with PTEs and timely deliverables. Studies show that teams raise productivity as the production process gets more complex (Boning et al., 2007).

Every PTE endures 4-5 instructional weeks (a total of 15 educational weeks). The first instructional element (PTE1) which emphasizes the parameters presentation of a digital design global system enables the first-year undergraduate students to explore and practice foundational theoretical knowledge across multiple practical small outcomes in labs software with a precise practical aim. These specific spatial tasks such as handling vector and raster tasks, creating and transforming coordinates, changing resolution and color model, digitizing raster images, relating Cartesian and geographical coordinates, basic algorithms exercises, 2D and 3D views representation, etc., were introduced in sequence from simple to more complex. Within this design context, a computational programming introduction in CAD environment (Visual LISP) was introduced in programming structure format with small, easy fundamental routines. During PTE1, new theoretical concepts were introduced to the students with no previous experience of digital design and design methodology. Their introduction to these issues was for many of them a difficult process. At the beginning of the courses, even the highly motivated students were not able to understand the relation between theory and practice and how they could reach this level of results without previous experience and knowledge. In the context of the second instructional element (PTE2), which emphasized software knowledge transfer¸ basic coordinates transformations and inter-functionality between 2D and 3D entities, practical issues were increasingly introduced. The majority of students started to express their positive impressions because of the more practical nature of the process. The fact that they were in groups helped them significantly to be adapted, to understand better the methodology, and share a common experience. Studies show that cooperative work among students can increase learning (Jensen et al., 2002) and their assignment to project teams ensure interdisciplinarity and balance their design capabilities (Kruck and Teer, 2009).

However, the university students preferred to use the software alone for training purposes, even though it was the least effective mode for developing 3D spatial skills, in contrast with middle school students who stated a preference for working with both the multimedia software and the workbook (Sorby, 2009).

In the context of the third instructional element (PTE3), which emphasizes to exploitation and models adjustment in modeling and simulation environments, the practical nature of the courses and the visible results in every step of the procedure (e.g. 3D modeling, imagery integration in buildings facades, digital city's sectors consolidation, etc) make the students more and more enthusiastic and available. At the end of the PTE3 students produced outstanding digital models. The 3D CAD training, despite the limited amount of time and the scarcity of resources, provided significant improvements in the spatial ability and 3D perception of space by confirming related researches (Onyancha et al., 2009).

However, during all the procedure steps, the students have encountered numerous problems, such as (a) in 3D spatial perception and architectural views (views, slices, isometrics, etc), (b) in methodology matters and processes synergy, and (c) in technical issues such as interfaces and communication between software. In particular, some students had difficulty passing from 2D (plan) to 3D isometric projections and vice versa. However, due to over simplification and lack of many 3D features in isometric drawings, they sometimes were confused and prone to errors. These errors are mostly missing features and some are extra features or misrepresented features (Yue, 2006). The problem of understanding views and slices projections persisted in all phases of the procedure independently of the intensive practical nature of the task. As a solution, it is proposed that multiple projection exercises with plasticine entities be used in order to re-fabricate and adjust continuously the plasticine entities as in the digital projection. This approach significantly enhanced the students' spatial perception and digital projection alternation understanding. The prominence afforded to freehand sculpturing with plasticine entities provided all students with the opportunity to visualize solutions to spatial problems. The role of sketching via real entities construction or sculpturing in design education contributes to the development of visualization skills in group of students (Olkun, 2003; Lane et al., 2009). This approach provides students with easy unlimited access to shapes, sizes and functions by transforming, rotating, detaching, cutting, etc. The familiarization of the students with innovate aspects of digital design was based on interdisciplinary methodology involving research approaches, adaptation capacities in methodological and technical procedures, synthesis competence of different interfaces, software, etc. The students had no previous experience of digital design or even methodological approach experience. Thus, given the limited time and the inability coverage of many knowledge gaps, it was proposed, in each phase of the procedure, that practical methodology exercises with the minimum of data be used, clarifying the goal and its consequences each time and trying simultaneously to help and strengthen the 3D spatial perception. In addition, the repeated application of theoretical aspects and the customized micro-task specific training of basic transformations, related algorithms and programming oriented to the project requirements is a more effective way to allow students to focus on visualization and spatial skills (Leutner, 2000; Sorby, 2005) and helps the students to make communication between techniques and software easier.

Conclusions:-

Educational approach

This educational process research presented innovative techniques and methodologies of design and a representation of the broad architectural space as an alternative approach and architectural conception methodology with a critical use of software capabilities.

The methodologies, the computing processes and the methods of creation, simplification, modification, adjustment and the 3D model simulation which were presented necessitate a clearly architectural reflection and a critical approach adapted to the philosophy of the architectural conception process. The manipulation of the geometrical elements, during the methodology and process of the design, is an approach of proposing architectural changes capable of managing and 'guiding' the architectural conception.

The methods of design and modification of architectural forms, volumes and objects are prevented by the restriction of freedom of movement of the architect, planning engineer, etc. The engineer must 'protect' and 'adjust' their engineering conception process to the demands emerging from methodologies of digital design and representation.
On the other hand, the engineering conception process demands, in its turn, a critical approach adapted to the philosophy of the digital design so that one can "enjoy the fruit" of capabilities of digital design via a continuous change of geometry, precocious representation of space during the engineering conception (Kouzeleas, 2002)

Educational results

The educational results that ensue from the above described process are the following:

1. Creation of pedagogical thematic entities and definition of 'peripheral' methodological approaches and pedagogical actions of the educational process (e.g., structure, lesson plans, contents, etc);
2. Definition of roles and relations of the work groups, adjustment of knowledge and tools into the conception process;
3. Provision of new knowledge and participation in work groups;
4. Demonstration of an interactive educational approach of theory-practice and application of theoretical notions;
5. Introduction to innovative processes within a research approach;
6. 3D virtual representation of space.

Educational implications

The proposal for the content and the structure of this educational process, in any case, must (a) take into account the existent educational organization, (b) readjust existent conditions, ways and means of teaching and, if possible, (c) develop them based on innovative research and new means.

The educational process, the structure and the content can and must have direct relation with other corresponding courses in constituting an educational prelude or continuation of previous pedagogical practical processes and mutual cover and complementation of theoretical knowledge.

Perspectives:-

Through the results and integration of the proposed methodology and practice, a pilot virtual spatial environment can be built which can constitute a base for the development of specific applications related with engineering issues (e.g., design and analysis of space with use of conditional scenarios). Finally, this educational process can be used for the description of any area of interest in broad urban landscape scale or in architectural scale of a build-up area.

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