Sustaining Information in a Knowledge Intensive Environment

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Abstract
The architectural design studio in academia is a demanding work environment, where different types of information are extensively used. Students acquire and use this information from curricula, and research to propose and deliver a design project (an acceptable solution). This design project is typically guided and constrained by their knowledge of the design problems, and the means to solve them. Although the vast range of knowledge and information handled through the design studio is typically available from variable sources, many students, and for different reasons fail to find and benefit from this knowledge in a timely manner. The efficiency of the design process and the quality of its final product (the project) are negatively affected by this situation. This research views the design studio as a knowledge intensive educational environment, where information is considered a valuable resource that should be sustained. This research attempts to identify issues related to knowledge and information handling in the studio through inductive methods; explore different avenues to resolve the main research problem from a sustainability point of view; and to deductively reach a conceptual framework for a computer system that can sustain information and knowledge in such an intensive environment.

1. Introduction

At the Department of Architecture and Building Sciences at King Saud University, different design studios, deal with typical themes that complement one another, to buildup and enrich the students' experience throughout his education. The architectural design studio is a knowledge intensive educational environment due to the continuous need, to use and update different types of information related to the studio's projects and their settings on one side, and the continuous development and update of software and hardware used on the other side. To address these challenges, we need to consider a memory aid to the students and staff members, which can be implemented using a wide range of the available technologies.

1.1 Research problem

Although there is a great deal of typical information handled in each design studio either in a digital form, hard copies, scientific tours to similar projects, or lectures in different subjects related to the theme project -many students, either in the same semester or in the following semesters- fail to find, reach, or benefit from these types of information. In many cases, the efficiency of the design process and the quality of its final product (the project) are negatively affected by this situation. Students and staff of various design studios face almost the same typical difficulties.

1.2 Objectives

Based on an understanding of information problems and the needs of students and staff, this research attempts to propose a conceptual framework of a computer-based system to manage the design studio information in a sustainable manner.

1.3 Hypothesis

In the context of the architectural design studio, there are three main relations that could be considered, first the relationship between the efficiency of the design process and the availability of project's information. Storing this information in a computer system will enhance this relation (i.e., constructing a long term memory). The second relationship is between the content and organization of projects' information and the students' abilities to search discover and access this information. Selecting, decomposing, and relating studio projects' information will improve information retrieval process (i.e., representation and reasoning). And last, the third relationship between information sustainability and the students' abilities to share in the process of managing the system information. Learning and applying appropriate related technologies will enable students to achieve this role (i.e., digital library technologies).

1.4 Importance

Prior knowledge plays an important role in architectural design, especially in the early stages of the design process. Justifications of using prior knowledge in the design process have their foundations based on cognitive necessity *(Schank 1982), observations of architects at work (Darke 1984; Lawson 1984; and, Schon 1988), practicality and actual use (Colquhoun 1972 and Archea 1987)*. Prior knowledge brings the initial concepts into the consideration of the designers, from which they proceed to examine the goals and constraints that need to be achieved in a design description.

From such viewpoints, it can be perceived that the implementation of the proposed framework will provide a valuable tool for using and sustaining information in the design studio.

2. Literature review

Sustainability has become a complex term that is related to almost every aspect of our life. It has been expressed as meeting the needs of the present without compromising the ability of future generations to meet their own needs. The fact that design knowledge is crucial in aiding and shaping design concepts leads to the importance of sustaining such information and knowledge in a form that can be repeatedly reused.

From this viewpoint, this research brings many issues into considerations which are mainly related to design learning, information managing, and knowledge intensive environments.

The authors categorized the literature into: (a) learning approaches and paradigm; (b) information reusing strategies and framework; (c) information processing and management; and, (d) digital libraries support to information reuse and design education. The following summarizes some examples of these categories.

Learning approaches and paradigms in the digital age is an important field that will guide the formation of the proposed framework outline - *Oxman (1999 a,b)* chose to use the computational design studio as a unique form of pedagogical mechanism for design learning and argued that it will prove itself as a unique medium for design teaching. She proposed an educational model in which the explicit learning of design knowledge structures and related cognitive strategies are the main objectives. Gross and Yi-Luen (1999) identified six paradigms for integrating digital media in the design studio: using up-to-date software; integrating knowledge; collaborating through web applications; integrating virtual and physical communities; employing information technology in intelligent buildings; and, exploring new software tools and their effects on architectural design.

Information reusing strategies is strongly related to the field of information sustainability - Hicks et al. (2002) argued that the effective utilization of data, information and knowledge is the only way for organizations to achieve and sustain competitive advantage. They developed a framework for the requirements of capturing, storing and reusing information and knowledge in engineering design. Leea and Lee (2001) proposed a framework of an evolutionary design system incorporating design information and history to enable the storage and usage of design information in addition to shape manipulation. Wood and Agogino (1996) described an approach to providing the designer with case-based conceptual design information stored in a computerized form to solve similar problems in slightly altered contexts. Ball et al. (2001) described the development of a design-reuse system that maximizes the benefits of rationale capture and information retrieval while minimising the costs to the designer.

Information processing and management - Wood et al. (1998) argued that the Information retrieval could be the basis for access to the informal, unstructured information that is prevalent during conceptual design. They tried to establish an intermediate language in which design context can be captured. Yang (1998), (2005) developed methods for search and retrieval that allow access to past information and encourage design information reuse. They also examined, several approaches to build thesauri, using manual and automated methods related to information indexing and handling requirements of designers.

Digital libraries are considered one of the most important concepts in supporting information reuse. In a Special Issue of the journal of Information Technology in Construction (ITcon) on Digital Media Libraries, Martens and Jabi (2004) reviewed some of the important aspects of digital libraries: 1) the world-wide web has become the de-facto standard platform for online publication, stand-alone solutions are quickly giving way to web-based interfaces that require a modern web browser with a few standard plug-ins; 2) databases and web interfaces are capable of searching, retrieving, displaying and reasoning about multimedia artifacts such as images, video, sound clips, and 3D models; 3) to ensure the security and relevance of data, systems must have knowledge about their users; 4) the world-wide web offers the ability to support collaborative activity; and 5) reasoning about information requires the encoding of more information – meta-information. Metadata has become a crucial research topic for researchers wishing not only to share information in an organized manner, but to also allow systems and users to reason about the information they have. *Stouffs et al. (2004)* presented research on the development of a new methodology for the exploitation of precedent knowledge in design education. The contribution of this research is the introduction of a theory of adaptive systems, and the application of this theory to the construction of a new kind of digital media library in design education. Based on this theoretical approach, they reported on the development of the "InfoBase project", a research related to the usage of digital libraries that advance both design education and design research.

3. Levels of understanding of intelligent systems

In order to understand the different functional aspects of an intelligent system, different levels of understanding are used (Newell 1982, and Marr 1982). These levels are used to describe intelligent systems without being hindered by features of their implementation (i.e., programming code) (Chandrasekaran et al. 1992). According to Marr (1982) the separation of explanation levels, allows the study of the basis of information processing to be made rigorous.

The first level is commonly referred to as the knowledge level (Newell 1982). It is concerned with what we believe to be the semantics of intelligent behavior. The second level, is the symbolic level, it reflects how we think this semantic content can be syntactically created. The third level is the system engineering level (Smithers et al. 1990). It considers how we think this syntactic theory is to be engineered in artificial systems. These three levels of understanding represent three different views of the results of AI research (i.e., semantics, syntax, and system architecture).

In the following the research will attempt to derive a conceptual framework of an intelligent system based on the semantics of the critical issues involved.

4. Critical issues to the development of the framework

The following is a brief of the most important related issues to the development of the framework such as: the associations between learning theories and the design studio; the cognitive and computational bases of representation, reasoning, and knowledge; methods of design information decomposition as they will affect information in the proposed digital library; and, digital library concepts as it will be considered as the core of the proposed system.

4.1 Design Learning

Learning can be understood as a product and as a process. Learning as a product is approached as an outcome of some process. This approach has the virtue of highlighting a crucial aspect of learning (i.e., change). Learning as a process focuses on what happens when the learning takes place *("Learning Theory.", 2009)*. In this research more concerned with the later. This research grounds its propositions on three of the main learning theories: behaviorism, cognitivism, and constructivism. Behaviorism view that learning is based acquiring habits; it focuses only on the observable aspects of learning. Cognitivism tries to explain learning through the processes of inference using prior knowledge. Constructivism also recognizes the importance of prior knowledge, and additionally emphasizes that the learner actively constructs or builds new ideas or concepts *(Smith 1999c, 1999b).*

The design studio is typically accepted as the core of design education. Many of the traditions associated with the studio education are derived from the French design institute the Ecole des beaux Arts. To build the students' expertise, they are exposed to a simulation of the professional environment. This product oriented approach to learning design has some disadvantage that can be reviewed in literature such as *(Salama 1995 and Oxman 1999a).* A better understanding to some of the cognitive aspect of design learning has been explicated in the work of *Schon (1983)* on educating the reflective practitioner emphasized the importance of: *representation* of design problems and ideas of their solution; the interactive modes of visual *reasoning* and design ideation introduces a cognitive orientation to design reasoning as a foundation of design learning. *Oxman (1999b, 2001)* argued in favor of cognitive approaches which emphasize and exploit the explication of knowledge processes and knowledge structures.

This research adopts *Oxman's (2001)* proposed educational model in which the explicit learning of design knowledge structures and related cognitive strategies are the main objectives. Where learning in design is: 1) the ability to represent design knowledge; 2) the ability to manipulate the representations of design knowledge; and, 3) design education is the processes and media, which contribute to design learning. She suggested that an effective medium of design education should be in modeling the representation of design thinking.

To explicate issues that relate the learning process of the students to the proposed conceptual framework, the following briefly reviews representation, reasoning, and knowledge.

4.2 Representation, Reasoning and Knowledge

Representation is every symbol that “designates or expresses”. A drawing, a tune, a word, a thought, an image or an idea may be considered a representation and/or a symbol. The purpose of representation is that of communicating to the mind. Representation is the means by which humans refer to realities or their perceptual manifestations as a function of what they know about them. This is why representing is equivalent to thinking (Akin 1982). Representation binds thinking and computation according to the doctrine of AI pioneers Allen Newell and Herbert Simon: (1) thinking is information processing; (2) information processing is computation, which is the manipulation of symbols; and (3) symbols, because of their relationships and linkages mean something about the external world. In other words, a perfect simulation of thinking is thinking (Waldrop, 1990:63).

Thinking can be understood and modeled in terms of representational structures and the procedures that operate on them (i.e., reasoning). As a mental activity, reasoning allows the passage from certain propositions stated as premises to a further proposition by virtue of a logical connection which links the latter to the former. Chouraqui (1984) classified the principal methods used in AI to: classical logics, pattern-directed inference systems, nonclassical logics, plan generation, and non-monotonic and common-sense reasoning).

Pattern-directed inference is of particular importance to the context of this research, since it provides the base for processing data based on its structure, as in case-based reasoning (Kolodner, 1993) and model-based reasoning (Davis and Hamscher, 1988). Both types of reasoning act on cognitive-based information structures (i.e., representation of design knowledge as cases and prototypes). Case-based reasoning is a problem solving paradigm, which use specific knowledge of previously experienced, concrete problem situations (cases). Model-based reasoning provides the framework for a class of problem-solving techniques where models of objects are represented by their function, behavior, structure, and their relationships.

Knowledge differs from data or information in that new knowledge may be created from existing knowledge using logical inference. If information is data plus meaning then knowledge is information plus processing. Different knowledge types are used throughout the design process. Different categories include descriptive knowledge (objects), prescriptive knowledge (goals), operational knowledge (methods), events and sequences (temporal), meta-knowledge (self) *(Carrara et al. 1994:170).*

It is important to point that, while the representation and storage of relevant design information (i.e., content) is sufficient for retrieval, however, explanatory and guiding systems should use additional methods to organize this information, in an attempt to reveal the important relevant context beyond the information (the content).

4.3 Decomposition

Decomposition is a method that is widely applied to simplify and control design problems and their solution. Decomposition denotes the action of splitting a composed whole into its constituent parts. In problem-solving the assumption behind decomposition is that each sub problem can be solved independently of the other sub problems *(Maher 1990, Chandrasekaran 1990).*

In an explanatory and guiding system such as the proposed digital library, the decomposition plan should be based on the types of problems that students will deal with in the design studio. Such problems may be directly related to "what" is being designed, and/or at "what stage" it is designed. Decomposition is applicable to both the process and product of design. Decomposing the process can be apprehended as stages and/or as sequences of steps leading to a partial solution at some stage of design (e.g., a plan to achieve a task or goal). Decomposing the product can be conceived as segregating the whole (e.g., building) into parts (e.g., spaces). Decomposition of the product reflects a model-based view of the problem where function, behavior, and structure of domain objects are represented *(Chandrasekaran 1994:174).*

There are at least two methods to decompose the product of design according to *(Maher 1990, Keuneke 1991)*; these are structural and functional decomposition. Structural decomposition aggregates the domain objects (e.g., buildings) to sets of parts and sub-parts, such that relations between the parts are identified. Functional decomposition identifies the sets of parts responsible for a particular overall behavior that satisfies a required function (e.g., structural system, circulation system, thermal system, acoustical system, etc.). Functional decomposition can also be conceived as a structural organization based on functional components *(Keuneke 1991:22)*. The basic idea is that the components in any complex system will perform particular sub-functions that contribute to the overall function.

4.4 Digital libraries

Digital Libraries represent the meeting point of many disciplines and fields, including data management, information retrieval, library sciences, document management, information systems, the Web, image processing, artificial intelligence, and human–computer interaction (Candela et al, 2007).

Six core concepts provide a foundation for Digital Libraries: Content, User, Functionality, Quality, Policy, and Architecture. All six concepts influence the Digital Library framework, as shown in Figure (1)

> The *Content* concept encompasses the data and information that the Digital Library handles and makes available to its users. It is composed of a set of information objects organized in collections.
>
> The *User* concept covers the various actors (whether human or machine) entitled to interact with Digital Libraries. Digital Libraries connect actors with information and support them in their ability to consume and make creative use of it to generate new information.
>
> The *Functionality* concept encapsulates the services that a Digital Library offers to its different users, whether classes of users or individual users.
>
> The *Quality* concept represents the parameters that can be used to characterize and evaluate the content and behavior of a Digital Library.
>
> The *Policy* concept represents the set or sets of conditions, rules, terms and regulations governing interaction between the Digital Library and users, whether virtual or real. Examples of policies include acceptable user behavior, digital rights management, privacy and confidentiality, charges to users, and collection delivery.

The *Architecture* concept refers to the Digital Library System entity and represents a mapping of the functionality and content offered by a Digital Library on to hardware and software components.

These concepts (with exception of the architecture aspect) are discussed in section (5).

Digital libraries are typically web-based applications they are built around specific repository software. Some of the best known examples are DSpace, Eprints, Fedora, DLibra, and Greenstone Digital Library Software.

Rich information structures are required to express the complicated relationships that bind different types of design information decompositions as discussed in (4.3). To achieve this task, two strategies can be implemented:

the first is to decompose documents by content; and the second, is to separate syntax from semantics *(Tuncer et al. 2001)*.

Metadata is used to express a decomposition of content by using keywords that classify the document, while XML enables the separation of syntax from semantics. In web documents XML tags describe what the data between the

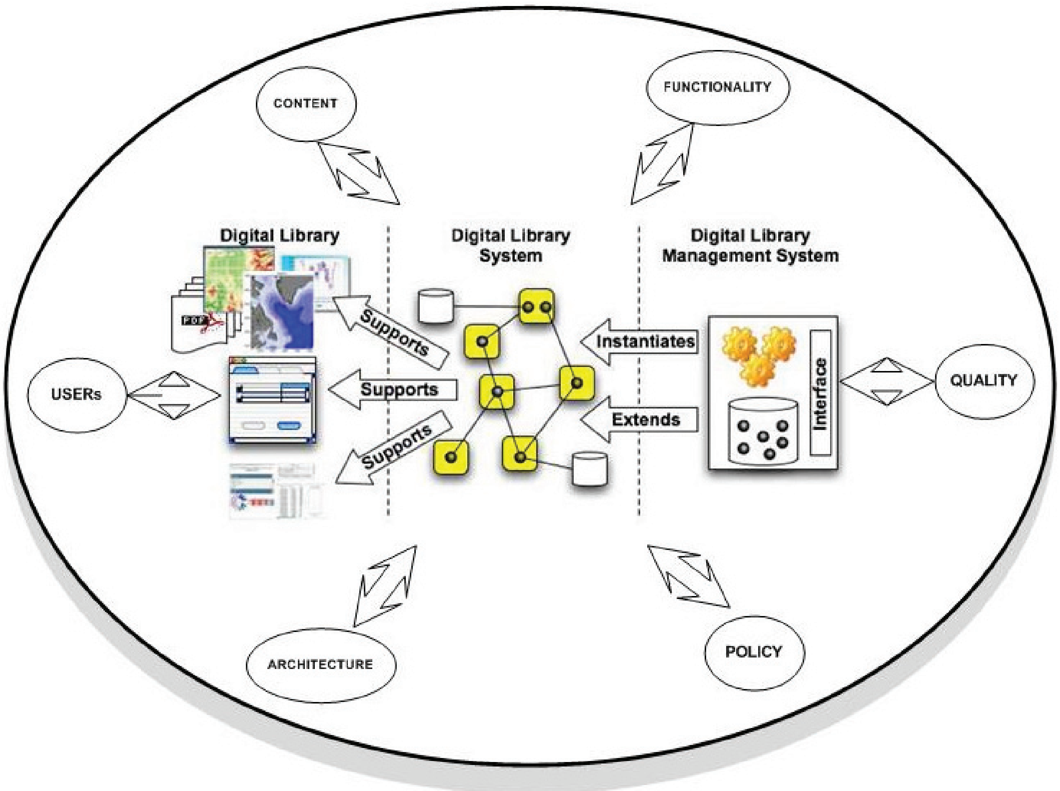

Figure (1) The digital library: main concepts
Source: *(Candela et al, 2007)*.

tags is. This facilitates the separation of content and the presentation part through use of the XML (Extended Markup Language) and XSL (Extended Style Sheet) languages. RDF (Resource Description Framework) is a way to express relations between objects, something XML does not allow you to do". RDF provides a general model for describing resources. Web-based structures (i.e., XML and RDF) facilitate the extraction of content and forge relationships between documents *(Christiansson 2003).*

The web content is given meaning through introduction of standardized name spaces and schemas such as XML Schema (specifying structure and data types) and RDF Schema that give meaning to the web based information containers.

5. Development of the Framework

We propose the following accumulative framework outline which includes:

an introduction to the target design studio; design project stages, adopted learning approaches; digital library information decomposition; users' roles in creating the DL content; and, system interaction.

The proposed system is composed of *people* (staff, students, and system managers), *digital library* (related studio and design information), *computational network* (input, output, and communication), and *learning environment* (design studio).

5.1 Learning Environment – The Design Studio

The Architectural design-3 (ARCH 340) is a 5 credit hours course at the sixth level of the bachelor degree of Architecture. The main objectives of the course are: to gain knowledge and skills to design multifunctional projects; to learn basic architecture programming concepts; and, to apply and refine previously learnt computer skills in the preparation and presentation of the proposed designs.

Teaching strategies include tutoring, lectures, scientific tours to similar projects, and architectural juries. Students' evaluation is based on continuous grading of studio work and architectural juries during different Milestone stages.

5.2 Design process - Project Stages

Normally the design studio project is delivered through four stages as shown in Figure (2):

Architectural program (three weeks): In this stage, students work in teams to prepare and present the architectural program of the term project. This stage depends mainly upon students' previous knowledge, data gathering from different sources, analysis of similar precedents, and ends with the assembly of the project space program and constrains.

Conceptual design alternatives (two weeks): In this stage, students start to synthesize their knowledge to partial, then overall design alternatives. They rely mainly on applying their understanding of the design problem, exploring and transforming building types and precedents representations into their own design alternatives.

Concept development, (5 weeks): In this stage, students rely on information related to building codes, engineering systems and interior design. Typically, they coordinate with other instructors from the faculty of engineering for developing, mainly structural and mechanical systems.

Project presentation (two weeks): In this stage, student rely mainly on information related to previous presentation cases, software techniques, tutorials, and FAQ related to digital presentation and project delivery methods and format.

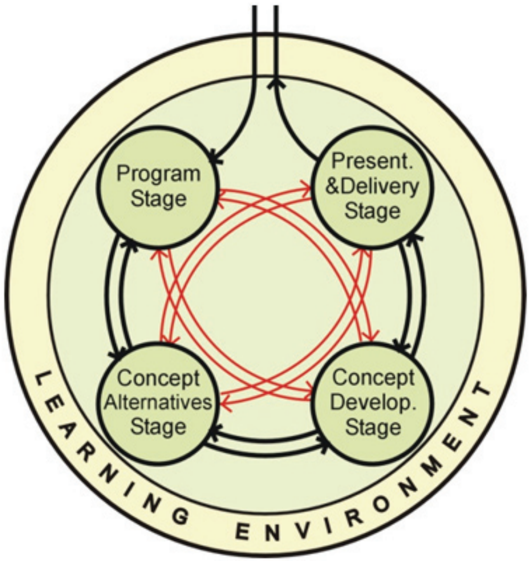

Figure (2) Design stages diagram

5.3 Design Learning – adopted approaches

Along the design process of the studio, students are typically subject to different learning approaches in which they interact in different manners as shown in Figure (3):

1. During the first stage and initial second stage, student learn in a memory-based manner, by relating previous knowledge to new concepts acquired during the data gathering, analysis to reach the final product (program) (i.e., Cognitivism).
2. During the propositional stages of the project (second and initial third stage), students interact in a process-based manner, by transforming, representing and re-representing their acquired knowledge into their own design (i.e., Constructivism).
3. During the presentation and final project delivery (fourth stage), students interact in a product-based manner, by concentrating on finalizing the project and cope with all constrains, and timeframe of final delivery requirements. (i.e., Behaviorism).

5.4 Information decomposition in the Digital library

Design students acquire information related to the project from different sources (hard and soft). The following could be a simple structural and functional decomposition for the targeted system digital library:

• Site information: contextual, soil and topography, climate, sensory, vehicular and pedestrian traffic, accessibility, rules and regulations (e.g., setbacks, allowable footprint area, etc.)

• Building information: historical and literature background, building typology, standards, engineering systems (structural, electromechanical, communications, fire and life safety, etc.), new trends and design criteria.

• Space and activities' information: norms and standards related to occupancy rates, area and volume requirements, furniture types and arrangement, etc.

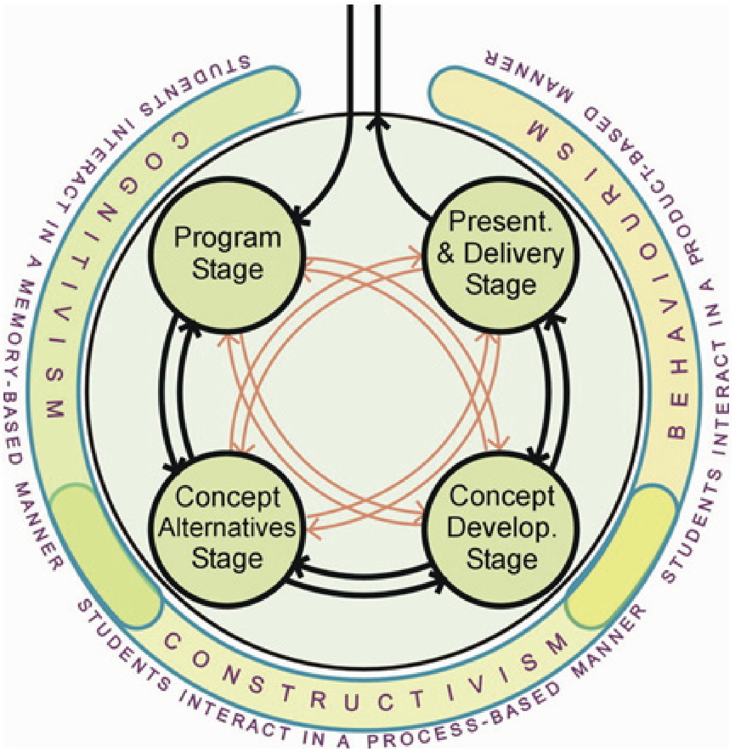

Figure (3) Adopted learning approaches and Students' interaction diagram

• Precedents information: program documents, design cases, building-based functions, similar design approaches, similar site contexts, project presentations

• Applications' information: manuals, tutorials, references, FAQ, techniques, how to accomplish certain tasks, general outline for information accessing, manipulating tools

• It is important to note that the relationships between each of the decomposed information components are a technical issue that can be handled at the systems representation level.

5.5 Roles, supportive efforts and interactions

The role of different users in the process of building the digital library information can be summarized as follows:

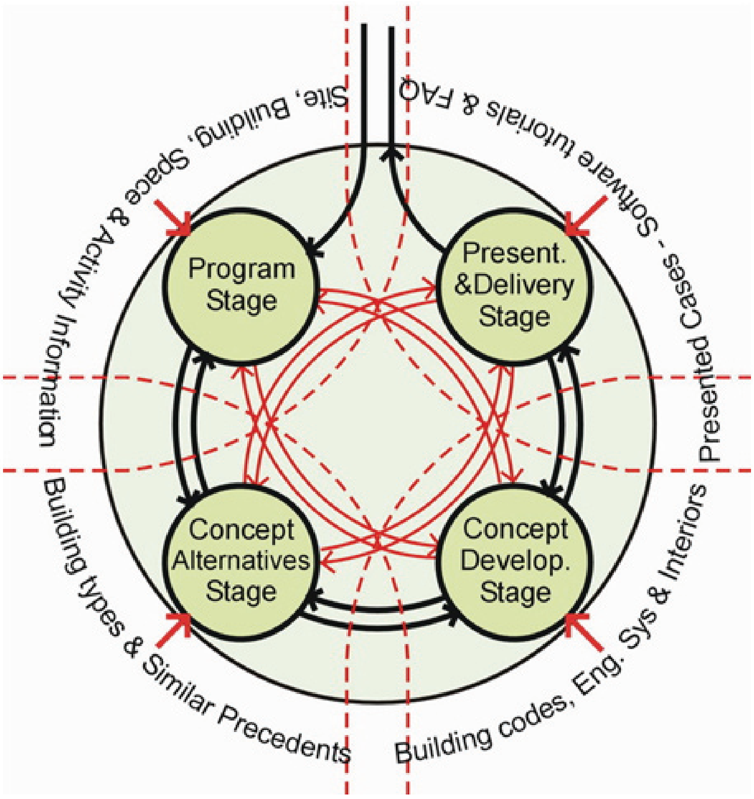

Figure (4) Information needs during design stages

• Staff members identify the type and range of information that should be

provided for the design studio. This is accomplished by aggregating the tasks in each design stage and selecting the related Information.

• Students gather the identified information throughout the design process in each semester.

• The system administrator classifies the gathered information, and properly stores/updates it in the digital library.

Administrative and research efforts are essential for complementing and supporting the implementation of the proposed framework:

• Administrative efforts in identifying the required processes that meet the student needs during different design stages throughout the project lifecycle.

• Educational and research efforts in selecting and developing suitable tools for the students' skills to perform his role.

Users' interactions within the proposed framework can be summarized as follows:

• Students interact and access the digital library during the project through searching, retrieving, storing, and updating the systems information.

• During the search and retrieval scenario there are three possibilities: 1) the information is found suitable and retrieved; 2) the information is found obsolete and should be updated; or, 3) the information is not found. In the second and third possibilities students need to acquire the information from external sources (hard or soft from staff, field or web sources), use it, and finally store it in a temporary account in the digital library.

• During the storage and update scenario there are two main tasks: the first is related to the system administrator (as previously noted); the second is related to students to represent-rerepresent, and then store their project deliverables at the end of each stage.

5.6 Outline of the proposed framework

According to the framework outlined in Figure (5), the following points should be noted:

• Associating each stage with a learning theory can help in deducing/inferring the proper learning strategies for that stage.

• Information decomposition scheme of the digital library is a complicated feat and is considered an implementation aspect of this conceptual framework (i.e., beyond the scope of this research paper).

• By the end of each stage, students update the system with new general and specific (student's project related) information.

• During project stages it is assumed that each student will have his own account on the system to save information related to his own project. By the end of the semester the students' products for each stage is integrated within the final product in a story-board accompanied by related textual information.

• Sustaining the student's product for each project stage has many advantages for the staff, students and learning processes: to aid in evaluating each student's work and to measure his advancements across different project stages; to fairly criticize and grade students of the same class by browsing and comparing their projects; to aid the student in self assessment; and, to backtrack to previous partial solutions.

• The story-board of all students' projects in a class with the textual related information will document the successes and weaknesses that could be further researched and investigated to develop a better studio pedagogy.

• At the end of each studio, students will store their projects, and update contextual data that might be needed by others in the following semesters, thereby completing the cycle of information sustainability.

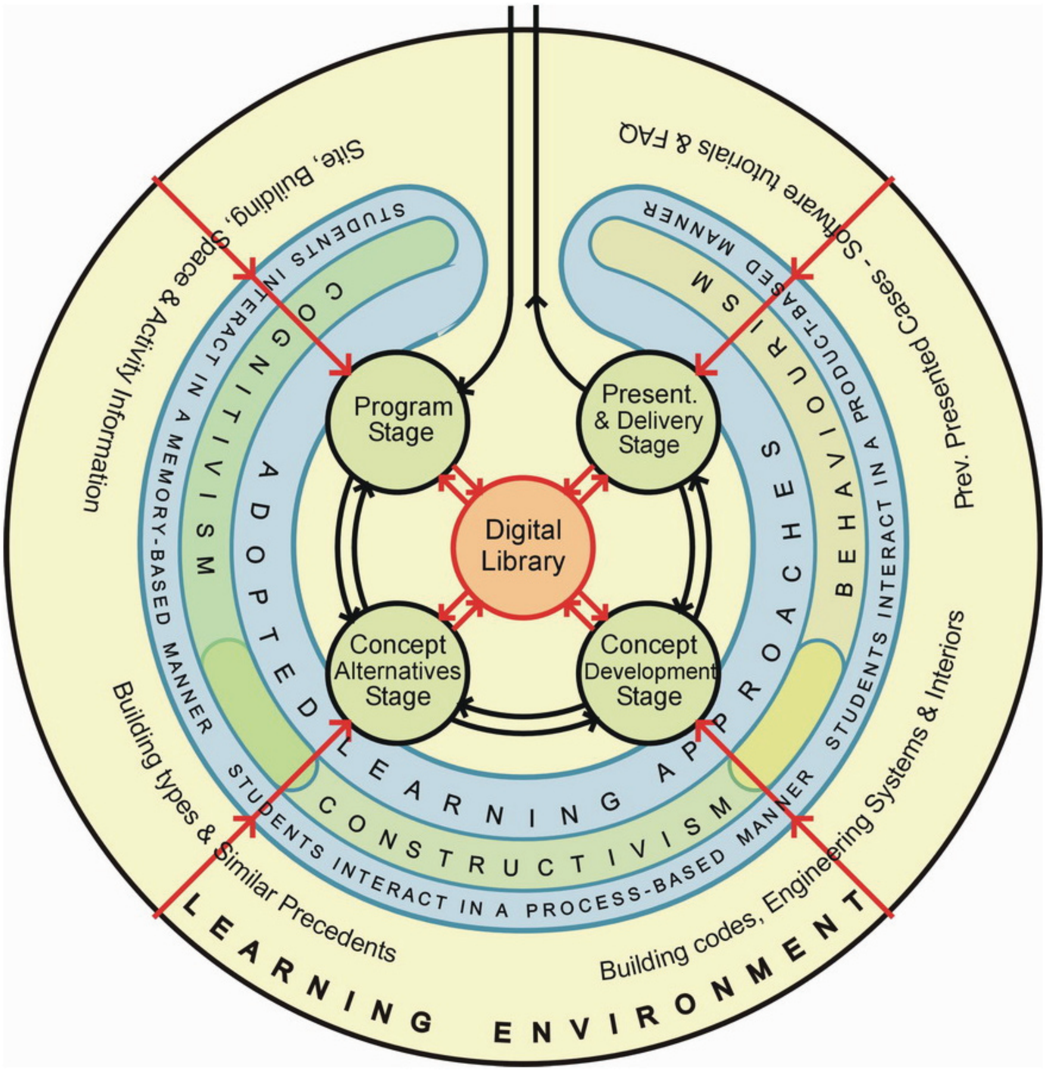

Figure (5) conceptual framework for information sustainability

6. Conclusions and Recommendation

The implementation of the proposed framework will provide students with an easy and efficient tool(s) to search, discover, access, and retrieve different types of information, which will help them to develop and refine their projects. Sustaining studio information in this framework is achieved through information preservation, reuse, maintenance, and update.

The proposed framework could be extended to include other design studios within the Department of Architecture and Building Sciences at King Saud

University as in the following accumulative stages:

1. The first stage: is the scope of this paper that targeted Design studio-3 (ARCH340), through which the initial prototype system is tested, evaluated and refined.

2. The second stage: implement the refined system separately in other studios (i.e., to allow for the tuning of the system with the theme of each studio).

3. The third stage: integrate the digital libraries of all studios to enrich the content and allow for cross fertilization.

4. The fourth stage: apply and link studios across different architectural schools in different countries to allow for cross evaluation and bench-marking of student projects.

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استدامة المعلومات في البيئات المعرفية

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ملخص:

يعتبر أستوديو التصميم المعماري في البيئات الأكاديمية أحد بيئات العمل الواعدة التي تستخدم فيها أنماط مختلفة من المعارف بصورة شاملة حيث يتم توجيه وتركيز معارف الطلاب فيها عن المشكلة التصميمية وأساليب حلها من خلال بحثهم عن واكتسابهم للمعارف والمعلومات في أثناء العملية التعليمية واستخدامها لتصميم وتسليم المشروع التصميمي (حل معماري مقبول). تكمن إشكالية البحث الرئيسة في أنه بالرغم من كم المعارف والمعلومات الذي يتم تناولها في مثل هذه البيئات التعليمية متوفر في صور متعددة فإن أغلب الطلاب، ولأسباب مختلفة، لا يتمكنون من التوصل إليها، أو الاستفادة منها في الوقت المناسب خلال مراحل التصميم المختلفة، وهو ما يؤثر سلباً على كفاءة العملية التصميمية ومنتجها النهائي (المشروع).ومن هنا فإن هذا البحث يعتبر أن استوديو التصميم المعماري بيئة معرفية مركزة تمثل المعارف والمعلومات فيها مصدراً قيماً يجب استثماره والمحافظة عليه من خلال تحقيق مبدأ الاستدامة. يحاول البحث استقراء الموضوعات المرتبطة بتناول المعارف والمعلومات في الاستديو، واستكشاف الوسائل المختلفة المرتبطة بتحقيق الاستدامة لها، ومن ثم استنتاج إطار مفهومي يمكن تطبيقه لحل إشكالية البحث من هذا المنظور.