Evaluation of the conceptual model of strategies effective in the development of the smartening of educational buildings

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Abstract— **The objective of this study was to determine the strategies effective in the development of the smartening of educational buildings. The population comprised students of architecture at the Islamic Azad University of Mahallat. Due to the small size of the population, all the members (68 individuals) were selected as the sample. The study was a descriptive-correlational research. The research tools comprised three questionnaires: 1) the researcher-made questionnaire of factors effective in the development of educational buildings, 2) the researcher-made questionnaire of the architect's lived experiences, and 3) the researcher-made questionnaire of perceived smartening of educational buildings. Data analysis was carried out using Pearson's Correlation test, stepwise multiple regressions analysis, and Structural Equations Modeling. In general, the findings revealed that the direct impact of smart materials able to change inner properties on the development of smartening of educational buildings was 0.137, the direct impact of smart materials able to exchange energy on the development of smartening of educational buildings was 0.121, the direct impact of smart materials able to change and exchange inner materials on the development of smartening of educational buildings was 0.126, the direct impact of information technology based on the systems on the development of smartening of educational buildings was 0.118, the direct impact of information technology based on structures on the development of educational buildings was 0.129, the direct impact of information technology based on services on the smartening of educational buildings was 0.129, and the direct impact of information technology based on managements was 0.124. Investigation of the experiential model using Structural Equations Modeling revealed that GFI=0.96, AGFI=0.93, RMSEA=0.0513, χ^2 =238.71, and df=94, which are indicative of the model's fitness.**

Index Terms— **educational buildings, smart materials able to change inner properties, smart materials able to exchange energy, information technology based on services & management.**

I. Introduction

The international symposium of architecture held in 1985 in Toronto stressed that, "a smart building is a combination of inventions (technological or otherwise) along with perfect management, leading to the return of the invested capital to a great extent. A smart building is the one equipped with a powerful communicative infrastructure which can continually react to the changing environmental conditions and adjust itself to them. It also allows the residents of the building to use the available resources in a more efficient way and feel more relaxed and secure. Like all other growing industries, there appear some competitions in this industry (Myer, 2002). By employing building smartening management system, one can increase the efficiency of the present facilities and optimize their function and also promote the service level using the enhancements and technologies of the day.

The facilities of the smart building include, 1) smart lamps and lighting system, 2) smart dimmer lighting system, 3) smart security- protection system, 4) smart cooling / heating and desirable air conditioning system, 5) smart fire alarm and management after fire system, 6) smart gas leak alarm system, 7) smart audio-visual system, 8) smart curtains and shutter control system, 9) smart watering system for watering gardens, orchards and plantations, 10) smart powerhouse system, 11) smart parking management system of the building. The techniques used in order to smarten up the building are categorized into two groups. 1) the methods in which there is no need for separate cabling in order to control different devices. In these techniques the signals produced by controlling devices are transferred via available power network in these buildings or with the help of RF signals, and controls the target device in destination (Markus, 1996). The most well-known technology in this group is X10 and Z-Wave. 2) The methods in which for controlling different devices we need to build another separate cable network in order to transfer the produced signals by controlling devices besides electrical wiring of the building. In this group, the most reliable technology is KNX technology.

There are different technologies used to perform the mentioned systems in homes some of which are mentioned below, 1. X10, 2. EIB, 3. Z-Wave, 4. C-Bus. X10 is an industrial standard for connecting used devices in Home Automation systems. This method basically uses electricity transmission system in order to send signals and intended controls. These signals use low frequencies of AC as digital information. Meanwhile a transmission based on sending radio signals is used in this method, as well. Z-Wave is a wireless bidirectional communication protocol which was presented with the alliance of Danish Zensys and Z-Wave companies. This technology is designed for low power and low bandwidths. Z-Wave offers the users a high quality network for a price equal to part of similar technologies' price. This is somehow innovative considering the concentration on using low bandwidth and substituting

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expensive hardware with software methods. It is also said that no wiring has been used for transmitting control signals in this technology. Transmitting control signals is done only through RF signals. C-Bus can be used for light control and other electrical systems via remote control. Meanwhile, it can interact with a protection system, audio-visual products or other electrical stuff. The C-Bus system is available in both wiry and wireless forms. Its gateway is also available for inter network connection in both wiry and wireless forms. The wiry C-Bus system benefits from a UTP Cat5 cable as a connection platform. Network wiring benefits from a free topological structure with the help of Cat5 in C-BUS. The maximum wire length used in C-BUS is around 1000 meters. However, this length can be increased by using Bridge in network. In a network one can install 100 diverse devices. This number can be multiplied using Bridges (Veer, 1997).

II. Theoretical framework

Gorjimahalbani and Haj Aboutalebi's (2009) studies showed that we are approaching the next generation of buildings; buildings on different levels which have totally ecological behavior and can react to the direct and indirect changes in their surroundings and adjust themselves to appropriate conditions by intelligently using compatible materials and new Hi-Tech devices. These innovations create new responsibilities for designers and architects and help them catch up with the accelerating technology and use these innovations in their designs. In his studies, Ritter (2007) showed that smart materials are categorized based on three features, 1- smart materials having the capability of change in their inner properties: comprising form-changing smart material, color-changing smart material, link-changing smart material. 2- smart materials having the capability of energy exchange: comprising light-emitting smart materials, electricity-producing smart materials, energy-saving smart materials. 3- smart materials capable of changing and exchanging inner materials. Addington et al. (2005) in their studies showed that there are some raw materials which have special applicable potential in the field of architecture and construction and could be used to smarten the constructions. Tourani's (2008) studies showed that smart materials almost have inexhaustible capability.

They can change in reaction to their surrounding environment while natural materials cannot. They can cause a positive change in architecture, construction and the lifestyle like the color on the wall which keeps itself clean and fixes itself in case of any damage. Also the wall which alarms in case of gas leakage or power failure. Smart materials can change colors according to instruction or produce electricity during the day and make it available at night. But their most important influence concerns the energy issue which is one of the most significant issues of the present century. Using the smart materials in buildings, one can benefit from optimizing energy consumption because, as it was revealed, most of the discussed materials and productions in this article receive their required energy directly or indirectly from their surrounding environment. In fact, smart materials are capable of balancing daily increase in the global demand for expensive energy resources and raw materials. Tristan d'Estree Sterk, one of the members of robotic architecture circle and designing smart buildings, is currently involved in working on samples of these buildings. Their main frame is a combination of rods and wires connected together by pneumatic muscles. A smart building is a building of which all the control subsystems are designed and implemented in a previously defined logical framework and are appropriate to the user status of the building. The control process in smart buildings is done through control systems which act smartly and supply the needs of the user and designer in order to achieve the objective of creating a smart building. One of the most well-known open standards in designing smart buildings is EIB standard. By implementing this standard in addressable modulus framework and relevant software, a vast scope of control subsystems and other equipment which in one way or another have the possibility of control by analogue and digital signals, are covered. Another type most well-known open standard in smart building designing is the local BACnet standard. By implementing this standard in local independent local controllers' framework (DDC controllers) and with their programming, there will exist the possibility of controlling all the SACS, LIGHTING, VAV, and HVAC systems in a totally independent and controllable way via central processor, as well as the possibility of creating connection and balance in order for them to interact with one another.

In this regard, a vast area of different types of analogue and controllable digital (Universal I/O) signals, both as input and output, will be covered. The findings made by Emamgholi (2010) demonstrated that smart architecture is the new attitude of some of architecture engineers toward the future of construction in the world; constructions which are able to adjust themselves to the environment inside and outside the building. Such buildings which imitate the reaction system of living creatures are able to react as a response to different atmospheric conditions such as wind, excessive heat and cold and changes in sunlight, or inside the building, having detected the conditions like increase in the number of people, they can show changes in their dimension and size. The findings made by Jani (2013) regarding the role of information technology in architecture showed that a smart building attempt to establishes a connection between accessibility, lighting, security, supervision, management and long-distance communication. The element of integration enables the systems to exchange information with one another. Information exchange among these systems makes it possible for the information release – which is the ultimate result- to be performed without any disruption. According to Utkin (1998), architect's lived experiences are a series of rules that, if followed, produce solutions to the problems, and are hence used to benefit from building control systems. According to the above discussion, the conceptual research model was designed as follows:

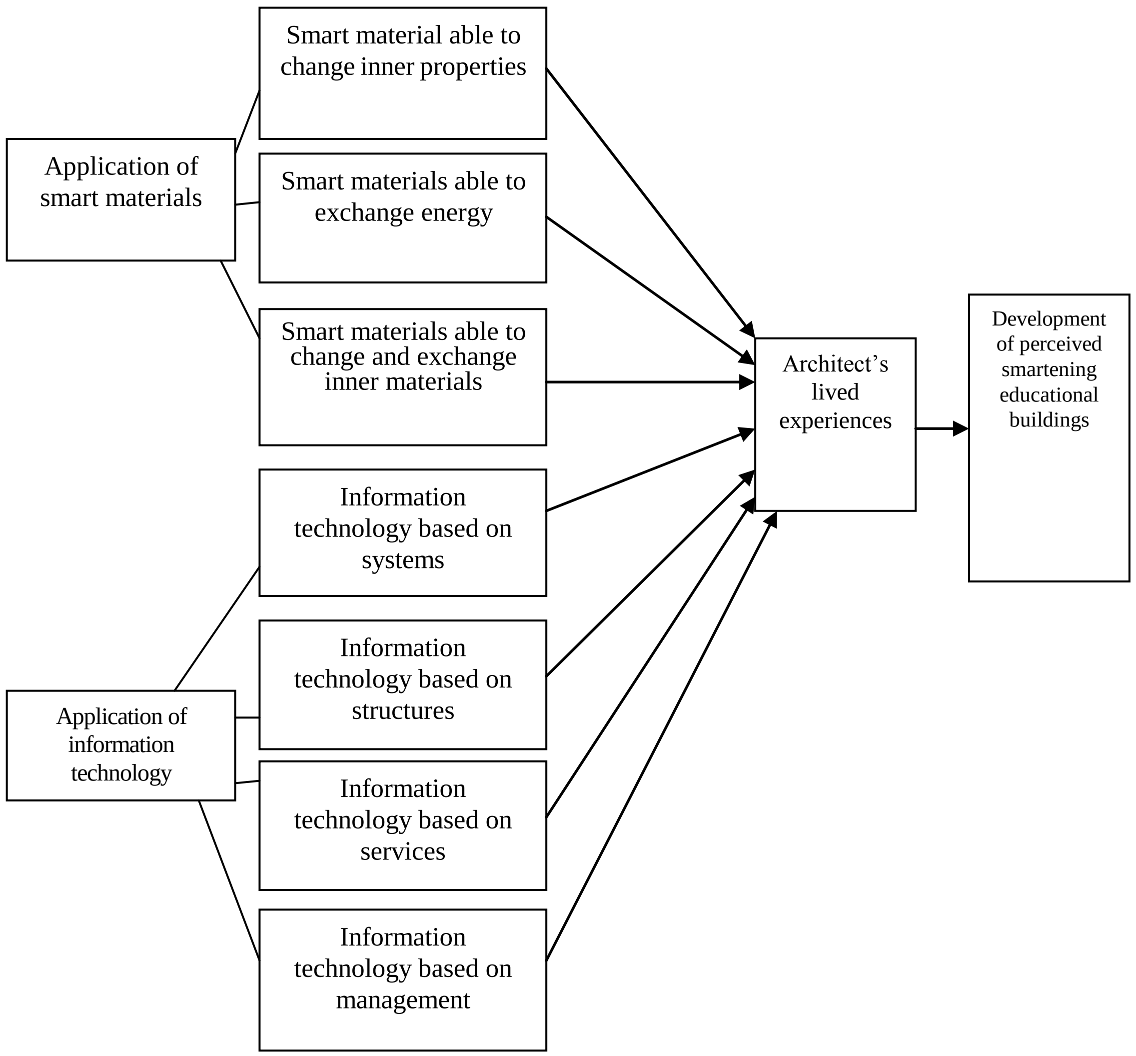

Figure 1. Conceptual research model concerning strategies effective in the development of the smartening of educational buildings with the mediation of architect's lived experiences

Research hypotheses

1. There is a significant relationship between the application of smart materials in the three aspects (i.e. smart materials able to change inner properties, smart materials able to exchange energy, and smart materials able to change and exchange inner materials) and the development of perceived smartening educational buildings.

2. There is a significant relationship between the application of information technology in the four aspects (information technology based on the systems, information technology based on the structures, information technology based on the services, and information technology based on the management) and the development of perceived smartening buildings.

3. Architect's lived experience mediates the relationship between the relationship of the application of smart materials and ICT to te development of perceived smartening materials.

III. Methodology

The population comprised students of architecture at the Islamic Azad University of Mahallat. Due to the small size of the population, all the members (68 individuals) were selected as the sample. The study was a descriptive-correlational research. The research tools comprised three questionnaires: 1) the researcher-made questionnaire of factors effective in the development of educational buildings, 2) the researcher-made questionnaire of the architect's lived experiences, and 3) the researcher-made questionnaire of perceived smartening of educational buildings. Data analysis was carried out using Pearson's Correlation test, Stepwise Multiple Regressions Analysis, and Structural Equations Modeling.

Table 1. Reliability coefficients of the research questionnaires

No.	Questionnaires	Item	Reliability coefficient (Cronbach's alpha)
1	**researcher-made questionnaire of factors effective in the development of educational buildings**	**18**	**0.91**
2	**researcher-made questionnaire of the architect's lived experiences**	**7**	**0.94**
3	**researcher-made questionnaire of perceived smartening of educational buildings**	**11**	**0.89**

Findings

Hypothesis 1: There is a significant relationship between the application of smart materials in the three aspects (i.e. smart materials able to change inner properties, smart materials able to exchange energy, and smart materials able to change and exchange inner materials) and the development of perceived smartening educational buildings.

Table 2. Correlation coefficient and the square of multiple correlation coefficient of the prediction of the development of perceived smartening educational buildings based on the application of smart materials in the three aspects

	β	*Sted.error*	βeta	*t*	*sig*	*R*	R^2	ΔR^2	*F*	*sig*
First stage										
Constant	9.527	1.536		5.526	0.001	0.623	0.388	0.567	/367 456	0.001
Application of smart materials able to change inner properties	3/724	1/468	0/426	11/746	0/001					
Second stage										
Constant	5.527	2.626		4.469	0.001	0.498	0.248	0.358	236.526	0.001
Application of smart materials able to change inner properties	3.362	0.379	0.637	12.837	0.001					
Application of smart materials able to exchange energy	0.825	0.462	0.426	6.836	0.001					
Third stage										
Constant	0.352	0.345		0.525	0.001	0.642	0.412	0.768	343.638	0.001
Application of smart materials able to change inner properties	0.527	0.569	0.379	0.537	0.001					
Application of smart materials able to exchange energy	0.739	0.343	.348	0.422	0.001					
Application of smart materials able to change and exchange inner materials	0.423	0.294	0.783	0.728	0.001					

According to the data presented in the above table, there is a significant relationship between the application of smart materials in the three aspects (i.e. smart materials able to change inner properties, smart materials able to exchange energy, and smart materials able to change and exchange inner materials) and the development of perceived smartening educational buildings. Based on the beta coefficient, 1 unit of application of smart materials able to change inner properties leads to an increase of 38 units in the development of perceived smartening educational buildings, 1 unit of application of smart materials able to exchange energy leads to an increase of 0.35 units in the development of perceived smartening educational buildings, and 1 unit of application of smart materials able to change and exchange inner material leads to an increase of 0.79 units in the development of perceived smartening educational buildings. Use of smart materials with the ability to change inner properties accounts for 39 percent of the variance of the development of perceived smartening educational buildings. Use of smart materials able to exchange energy accounts for 25 percent of the variance of the development of perceived smartening educational buildings.

Also, use of smart materials with the ability to change and exchange inner properties accounts for 41 percent of the variance of the development of perceived smartening educational buildings.

Hypothesis 2. There is a significant relationship between the application of information technology in the four aspects (information technology based on the systems, information technology based on the structures, information technology based on the services, and information technology based on the management) and the development of perceived smartening buildings**.**

Table 3. Correlation coefficient and the square of multiple correlation coefficient of the prediction of the development of perceived smartening educational buildings based on the application of information technology in the four aspects

	β	Sted.error	βeta	t	sig	R	R^2	ΔR^2	F	sig
First stage						0.738	0.545	0.629	562.458	0.001
Constant	6.527	0.582		5.624	0.001					
Application of information technology based on systems	3.735	0.563	0.358	7.926	0.001					
Second stage						0.935	0.874	0.834	728.621	0.001
Constant	5.472	1.472		4.823	0.001					
Application of information technology based on systems	4.838	0.560	0.572	8.895	0.001					
Application of information technology based on structures	0.897	0.629	0.469	6.724	0.001					
Third stage						0.376	0.141	0.482	457.678	0.001
Constant	0.928	0.764		4.935	0.001					
Application of information technology based on systems	3.482	1.452	0.784	6.785	0.001					
Application of information technology based on structures	0.766	0.479	0.385	7.893	0.001					
Application of information technology based on services	3.784	0.748	0.462	11.934	0.001					
Fourth stage						0.871	0.758	0.529	382.789	0.001
Constant	0.381	0.472		5.799	0.001					
Application of information technology based on systems	0.584	0.579	0.564	8.781	0.001					
Application of information technology based on structures	1.482	0.745	0.295	6.496	0.001					
Application of information technology based on services	3.849	3.283	0.582	8.893	0.001					
Application of information technology based on management	1.746	1.678	0.763	14.678	0.001					

According to the data displayed in the above table, there is a significant relationship between the application of information technology in the four aspects (information technology based on the systems, structures, services, and management) and the development of perceived smartening buildings. According to the Beta coefficient, 1 unit of application of information technology based on systems leads to an increase of 0.56 units in the development of the perceived smartening educational buildings, 1 unit of application of information technology based on structures leads to an increase of 0.30 units in the development of the perceived smartening educational buildings,1 unit of application of information technology based on services leads to an increase of 0.59 units in the development of the perceived smartening educational buildings, and 1 unit of application of information technology based on management leads to an increase of 0.77 units in the development of the perceived smartening educational buildings. The results also of information technology based on services accounts for 14%, and application of information technology based on management accounts for 55% of the variance of the show that use of smart material able to change inner properties accounts for 39% of the variance of the development of perceived smartening educational buildings. In addition, the findings also reveal that application of information technology based on systems accounts for 55%, application of information technology based on structures accounts for 87%, application development of the perceived smartening educational buildings.

Hypothesis 3. Architect's lived experience mediates the relationship between the relationship of the application of smart materials and ICT to the development of perceived smartening materials.

Table 4.Direct and indirect effects of the application of smart materials and information technology on the development of educational buildings

Row	**Variables**	**Architect's lived experiences**			**Development of perceived smartening educational buildings**		
		Direct effect	**Indirect effect**	**Total effect**	**Direct effect**	**Indirect effect**	**Total effect**
1	**Architect's lived experiences**	**0**	**0**	**0**	**0.149**	**0**	**0.149**
2	**Application of smart materials able to change inner properties**	**0.126**	**0**	**0.126**	**0.128**	**0.019**	**0.147**
3	**Application of smart materials able to exchange energy**	**0.121**	**0**	**0.121**	**0.125**	**0.018**	**0.143**
4	**Application of smart materials able to change and exchange inner materials**	**0.118**	**0**	**0.118**	**0.122**	**0.017**	**0.139**
5	**Application of information technology based on systems**	**0.127**	**0**	**0.127**	**0.131**	**0.019**	**0.15**
6	**Application of information technology based on structures**	**0.124**	**0**	**0.124**	**0.126**	**0.018**	**0.144**
7	**Application of information technology based on services**	**0.120**	**0**	**0.120**	**0.118**	**0.018**	**0.136**
8	**Application of information technology based on management**	**0.128**	**0**	**0.128**	**0.123**	**0.019**	**0.142**

The data presented in the above table demonstrate that the direct effect of architect's lived experiences on the development of the perceived smartening educational buildings is 0.149, the direct effect of the application of smart materials with the ability to change the inner properties is 0.128, the direct effect of application of smart materials able to exchange energy is 0.125, the direct effect of application of smart materials able to change and exchange inner materials is 0.122, and all these effects are considered significant. The findings also show that the indirect effect of the application of smart materials with the ability to change the inner properties on the development of perceived smartening educational buildings is 0.019, the indirect effect of application of smart materials able to exchange energy is 0.018, the indirect effect of application of smart materials able to change and exchange inner materials is 0.017, the indirect effect of the application of information technology based on systems is 0.019, the indirect effect of the application of information technology based on structures is 0.018, the indirect effect of the application of information technology based on services is 0.018, the indirect effect of the application of information technology based on management is 0.019, and all these effect are considered significant. This is indicativeof the fact that architect's lived experience mediates the relationship between the relationship of the application of smart materials and ICT to the development of perceived smartening materials.

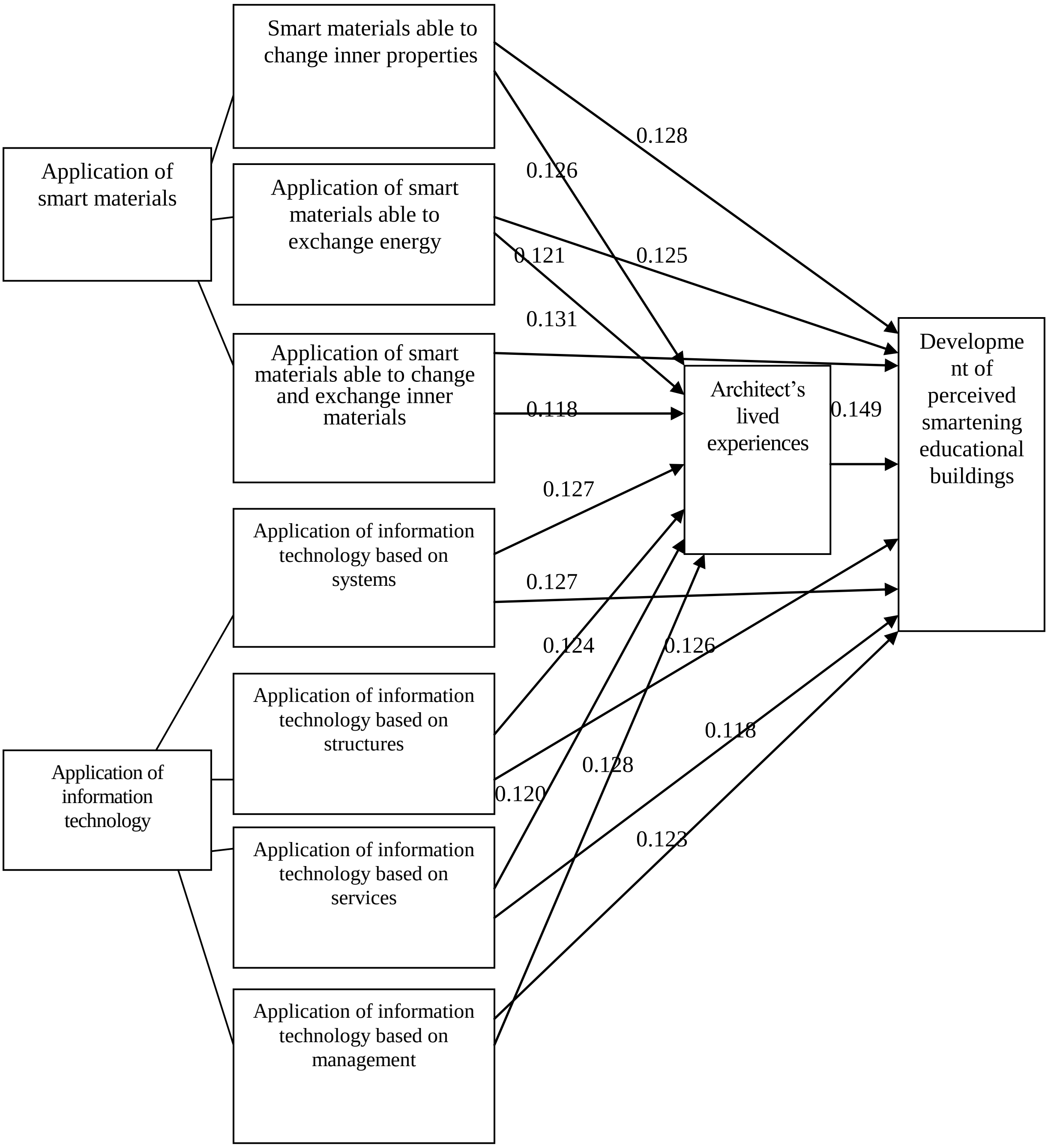

Figure 2. Conceptual research model concerning strategies effective in the development of the smartening of educational buildings with the mediation of architect's lived experiences

Table 4. Fitness of the proposed model concerning strategies effective in the development of the smartening of educational buildings with the mediation of architect's lived experiences

Fitness indices	Estimate
Goodness of fit index (FGI)	**0.96**
Adjusted goodness of fit index (AGFI)	**0.93**
Root mean square error of approximation (RMSEA)	**0.0513**
Chi square(χ^2)	**238.71**
Degree of freedom (df)	**94**

According to the above table, GFI=0.96, AGFI=0.93, RMSEA=0.0513, χ^2 =238.71, and df=94, which are indicative of the model's fitness

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IV. Discussion and conclusions:

At the present time, we are approaching the next generation of buildings; buildings with different degrees which have totally ecological behavior and can react to the direct and indirect changes in their surroundings and adjust themselves to appropriate conditions by intelligently using compatible materials and new Hi-Tech devices. Therefore, it is necessary to make efforts to develop smart buildings and try more than before to lay the foundation for smartening of buildings. With respect to the first hypothesis, the findings reveled that there is a significant relationship between the application of smart materials in the three aspects (i.e. smart materials able to change inner properties, smart materials able to exchange energy, and smart materials able to change and exchange inner materials) and the development of perceived smartening educational buildings. Based on the beta coefficient, 1 unit of application of smart materials able to change inner properties leads to an increase of 38 units in the development of perceived smartening educational buildings, 1 unit of application of smart materials able to exchange energy leads to an increase of 0.35 units in the development of perceived smartening educational buildings, and 1 unit of application of smart materials able to change and exchange inner material leads to an increase of 0.79 units in the development of perceived smartening educational buildings. The study by Ritter (2007) revealed that smart materials are classified into three categories: 1) smart materials able to change inner properties including transforming smart materials, color-changing smart materials, and link-changing smart materials, 2) smart material able to exchange energy including light- emitting smart materials, electricity-generating smart materials, and energy-saving smart materials, and 3)smart materials able to change and exchange inner materials. Addington and Schodek (2005) showed that smart materials are raw materials which have special and applicable potential in the field of architecture and construction, and which can be used to smarten up buildings. With regard to the second hypotheses, the findings demonstrated that there is a significant relationship between the application of information technology in the four aspects (information technology based on the systems, structures, services, and management) and the development of perceived smartening buildings.According to the Beta coefficient, 1 unit of application of information technology based on systems leads to an increase of 0.56 units in the development of the perceived smartening educational buildings, 1 unit of application of information technology based on structures leads to an increase of 0.30 units in the development of the perceived smartening educational buildings, 1 unit of application of information technology based on services leads to an increase of 0.59 units in the development of the perceived smartening educational buildings, and 1 unit of application of information technology based on management leads to an increase of 0.77 units in the development of the perceived smartening educational buildings. The findings made by Jani (2013) regarding the role of information technology in architecture showed that a smart building attempt to establishes a connection between accessibility, lighting, security, supervision, management and long-distance communication. The element of integration enables the systems to exchange information with one another. Information exchange among these systems makes it possible for the information release – which is the ultimate result- to be performed without any disruption. With respect to the third hypothesis, the findings demonstrated that architect's lived experience mediates the relationship between the relationship of the application of smart materials and ICT to the development of perceived smartening materials. According to Utkin (1988), lived experiences are a series of rule obeying which increases the chances to solve the problems. This characteristic is a kind of ability using which the system takes lessons from past experiences. Decision-making scheduling is an example of system reprograming based on past experiences whereby the system is readjusted on the basis of the new given information. Information is given either by sensors or individuals. In a conference room, the system could detect increase in the number of individuals present and hence reduce the temperature of the room from 75 degrees Fahrenheit to 65 degrees so as to control the heat resulted by the presence of 20 individuals in the room. However, after this action which is performed automatically, the person in charge of the control management realized that the temperature must be reduced for 65 to 58 degrees and hence he/she makes the changes manually. Therefore, during this procedure, the system learns that its calculation for the 10-degree reduction of temperature has not been so precise. Hence, next time, when there are 30 individuals present, using the past experience, the system tries to calculate the heat resulting from each individual. This ability proves very instrumental in situations such as fire as well as in maintenance. According to the findings of this study, GFI=0.96, AGFI=0.93, RMSEA=0.0513, χ^2 =238.71, and df=94, which are indicative of the model's fitness.

Since one of the factors effective in improving students' learning is their place of study, using breakthroughs done in the area of architectural smartening of buildings, efforts must be made to apply the techniques to smarten up schools and educational buildings in order to control students and reduce in educational costs.

REFERENCES

[1] Addington, D. Michelle; Schodek, Daniel L. (2005). "Smart Materials and Technologies for the Architecture and Design Professions", Architectural Press/Elsevier: Oxford.

[2] Imamgholi, A. (2010). "Smart Engineering or Intelligent Engineering," First National Conference on New Technologies in Engineering Science.

[3] Jani, M., Mehmando'I, H. (2013). "Role of Architecture and Smart Buildings (Sensors in Architecture)," Second National Conference on Climate, Building, and Optimization of Energy Consumption.

[4] Mahalbani, Y., Haj Abutalebi, E. (2009). "Smart Materials and Their Role in Architecture," *Journal of Rural Housing and Environment*.

[5] Markus Kohler.(1996). Vision Based Remote Control in Intelligent Home Environments, Published in:3D Image Analysis and Synthesis, pages 147-154(ISBN3-89601-000-X).http://1s7-www.uni-dortmund.de/.

[6] Myer, K. (2002). "Handbook of Material Selection" John Wiley & Sons, Inc., N.Y.

[7] Ritter, A. (2007). "Smart Materials in Architecture, Interior Architecture and Design", Birkhauser, Switzerland.

[8] Tourani, A. R. (2008). "Future of Fundamental Particles in Architecture," *Journal of Architecture and Building*, No. 16, summer.

[9] Veer, P. van der and Sariyildiz, I.S.(1997). "Integrated Building Design Decision Support Systems", in: *Proc.*Applications of Artificial Intelligence in Engineering, AIENG 97, July 6-9, Capri, Italy