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The Strategies of Outspreading Smart Materials in Building Construction Industry in Developing Countries; Case Study: Iran

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Abstract: Industrial development and promoting new technology has led to produce new building materials. "Smart materials" are one of the result of scientific genius and achievements of human knowledge in different technical and administrative fields. These kinds of materials can have their suggested roles when extensively be welcomed by the professional activists in the field of construction industry; however in the case of Iran, it is obvious that it is not adopted a desirable trend. This paper by introducing smart materials, aims to figure out the challenges through its development and wide-spread usage of them in developing countries. In this regard, based on Bloom's taxonomy and cognitive domain, it analyse the "Cognitive Domain" of those who involved in design and built procedure of buildings about "smart materials": Teachers (university staff), designers (consultant) and practitioners (builders). Research method in this study is case studies and combined strategies. The results show that the most important challenge toward this issue in Iran, as one of developing countries, is lack of information and cognition about smart materials. Therefore it is necessary to bold the role of education and training to enhance the usage of smart materials in the case of Iran. The originality of the paper is laid in its purpose of exploring practical challenges of the outspreading new technologies in case of Iran as one of developing countries.

Keyword: Smart Materials, Building Construction Industry, Developing Countries, Bloom Taxonomy, Cognitive Domains.

1-Introduction

"The development of modern industry is essentially material. Nevertheless, in following its material urge, industry unconsciously creates new powers of expression and new possibilities of experience." (Gideon, 1982, p.5)

Smart materials with the age of almost three decades have been laid in the procedure of new materials. They have the ability of changing their properties through external stimuli such as stress, temperature, moisture, electric or magnetic fields. This group of material with their "inherent active behavior" would be considered not just a material but a technology (Addington, 2005, p.29), due to the fact that they have three main components of intelligent systems- sensors, actuators and processors- in themselves simultaneously. Although smart materials provide different and new facilities besides having small size, they are not wide spread in Iran as one of the developing countries as other countries. In this regard, we set out questionnaires for building construction activists (consultant, builders and teachers) as case studies (Groat & Wang, 2002, pp.341-373). In order to define the states of them and give strategies to solving this challenge in Iran, cognitive domain of Bloom taxonomy is applied in this survey.

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2- Smart Materials

NASA defines smart materials as «materials that ‘‘remember’’ configurations and can conform to them when given a specific stimulus» (http://virtualskies.arc.nasa) .Encyclopedia of chemical technology defines that smart materials and structures are those objects that sense environmental events, process that sensory information, and then act on the environment (Kroschwitz, 1992). Smart materials are relatively new term for materials and products that are able to reversibly change their properties in response to different stimulus. The five fundamental characteristics distinguishing a smart material from the more traditional materials used in architecture are defined as follows (Addington, 2005, p.10):

- Immediacy: they respond in real time;
- Transiency: they respond to more than one environmental state;
- self -actuation: intelligence is internal to rather than external;
- Selectivity: their response is discrete and predictable;
- Directness: the response is local to activating event.

All smart materials can be grouped into three types (Ritter, 2007, pp. 43-46):

1- property changing materials;
2- energy exchanging material;
3- Material exchanging.

The first class has a great number of potential applications in architecture while the second class would be applied in building servicing such as actuators and sensors and the third class are acted as insulator.

Application of smart materials according to their place can be neatly classified into the following systems: Façade, lighting, energy and structural system (Addington, 2005, pp. 165-180). Most application of smart materials is in sensors but the most visible and observable application of them in building regards to façade system. Smart windows (Lampart, 2004, pp.28-35) (Cupelli and others, 2009, pp.2009-2012) (Granqvist, 1998, pp.200-215) and façade materials (Ritter, 2007, pp.73-182) as components of façade system, are the authorities of an architect that chosen according to the desired application.

Smart materials in procedure of architecture design	Smart windows	thermochromic
		Phtochromic
		thermotropic
		electrochromic
		Liquid crystal
		Suspended particle
	facade Material	Self-cleaning material
		Self-cleaning glasses
		Thermochromic cements

Table 1- smart materials which are in the process of architecture design, Source: Authors

3- Challenges toward development of Smart Materials

Although smart materials can be effective and impressive to environmental crisis issue, they don’t have wide-spread usage in building construction. The reason of not being widespread can be proposed in two fields: theoretical and applied.

a. Theoretical field: In Theoretical field, limited knowledge and limited raw material cause a new technology not to be spread widely. About smart materials, these two features do not exist while it is conceived that the supply of various types are different in each material. So the reason of not being widespread should be found in other field.

b. Applied field: In applied field, three main features exist: fear of risk, lack of cognition and high cost. To overcome these barriers, smart materials should be introduced to people. Advertisements play a great role in this way. In the next stage, smart materials should be utilized in highly visible places. Through this way, people would be familiar with and encourage using them. For example, in America first of all thermochromic chairs and electrochromic toilet stall doors exposure to public, then they were implemented in Diller and Scofidio’s Brasserie Restaurant on ground floor of Seagram building(Addington, 2005, 4). Finally, general acceptation of using smart material causes high request and leads to mass production which decrease the cost.

As a result, recognition is the primarily step in both fields of development. This problem needs careful and precise observation in order to analyze challenges and give solutions. As smart windows are not being wide- spread of usage in Iran, in-person questionnaire and in-depth interview techniques were utilized.

3.1. Bloom's Taxonomy and Cognitive domain

The Bloom's taxonomy has been employed to study the cognitive statues of those who involved in building industry i.e. **Teachers** (academic staff), **Designers** (consultant companies) and **Practitioners** (builder companies).

In Bloom theory, the cognitive domain includes knowledge and the development of intellectual skills. There are six major classifications, which are listed in order below, starting from the simplest behaviour to the most complex. The categories can be thought of as degrees of difficulties. That is, the first one must be mastered before the next one can take place (Bloom, 1956):

Level 1-Knowledge: Exhibit memory of previously-learned materials by recalling facts, terms, basic concepts and answers

Level 2-Comprehension: Demonstrative understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas

Level 3-Application: Using new knowledge. Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way

Level 4-Analysis: Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations

Level 5-Synthesis: Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions

Level 6-Evaluation: Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria.

3.2. Questionnaire

Based on Bloom's classification for cognition domain, a questionnaire was designed in order to explain the cognitive statues of the statistical society about the smart materials, as one of the most common smart material in buildings (Table 2). A survey was done among three groups involved in construction of buildings consisting of twenty members of academic staff, ten experienced consultant, companies and ten builder companies.

Level	classification	Skills Demonstrated	Questions
1	Knowledge	observation and recall of information	Do you have any information about "smart windows"?
2	Comprehension	understanding information	Do you know the difference of these kinds of materials with the others?
3	Application	use information	Do you know their kinds and the state of using in building?
4	Analysis	seeing patterns	Do you know their components and constituent layers?
5	Synthesis	use old ideas to create new ones	Do you know how to use "smart windows" in order to improve building's function?
6	Evaluation	compare and discriminate between ideas	Do you know the necessity of using these components?

Table 2-Questionnaire based on Bloom Taxonomy of Cognitive Domain, Source: Authors

4- The Survey Results

As the result of the survey, none of the consultant companies has full recognition of smart windows; just 60% of them have primary recognition (level 1 and 2 of taxonomy) of these materials and 40% remaining have no information about them. On the other hand, no company has applied these materials in its projects, and this is rooted in not having enough recognition of smart materials. (Table 3)

statistical society	Level of Challenges Challenges						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Designers (Consultant)	4	2	4	0	0	0	0
Practitioners (Builders)	8	2	0	0	0	0	0
Teacher (member of academic staff)	2	3	7	4	2	1	1

Table3. Survey result, source: Authors

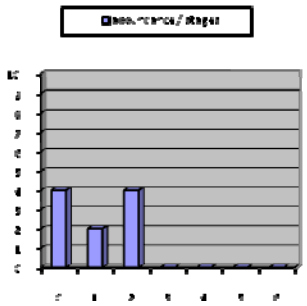

Fig1-cognitive skills of consultants

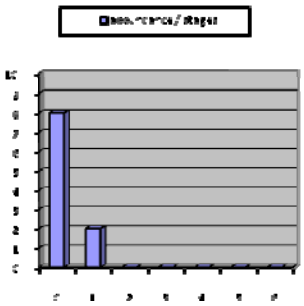

Fig2- cognitive skills of builders

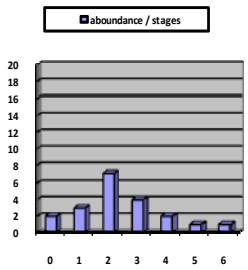

Fig3- cognitive skills of teachers

Also about builders, none of them has full recognition of smart materials; only 20% of builders have the first level of cognition about this new product and others not even have heard the name of these materials. However just 20% had primary recognition and 80% of them didn't have any information, none of them show enthusiasm for getting more information about them, seeing samples or constructing samples. In academic staffs and teachers group, 5% of them have full recognition of smart materials, although in other groups none of them has complete information about these materials and just 10% has no information. The most Frequency is in second stage, which declares that there is need to introduce these new products to them more in order to promote knowledge in this field and make academic staffs more familiar with new products and technologies. Overall, this group is the one who have more information of smart materials and new technologies.

5-Conclusion

The conventional model for implementing a new product and developing it, is a linear process consisting of four major phases: request and demand, design, produce and apply. The first step before this process is to have enough knowledge and cognition about the product.

Iran's experiments show that status of smart materials in building industry has not still passed the cognition steps. In theoretical phase, it is required for the involved groups to be aware of the functions and applications of new products. To comply with this necessity, advertisement can be very effective and as a result of that, amount of requests and demands would be increased considerably. In design field, lack of awareness and appropriate cognition of new products by specialists particularly designers, resulted in not using them in their projects. So, there is a need to instruct new technologies to designers.

In practical field in Iran, construction companies are not determined to produce new products with modern technologies voluntarily and without request of market. In this regard, being aware of producing and applying smart materials is not as important as having large amount of demands. Experiments regarding to spreading new products show that there should be desired customers and demands for new products in order to encourage constructing companies to produce and implement such materials.

In general, lack of correct cognition of smart materials and also being unfamiliar with the result of using such materials, are considered the most important challenges of building construction in Iran in the field of implementing smart materials. For solving this problem, it is necessary to promote the cognition of involved mans. Among involved groups, academic staffs are the one who have more information of new technologies. Consequently, they play have duty of introducing them to designers, construction companies and people. So to synchronize academic staffs with global developments, holding conferences and seminars, and providing facilities to participate in international conferences and exhibitions are necessary. Also consultant companies, who have more relationship with people than other involved groups, can be considered as an intermediate between people and new technologies. Therefore they can play an important role in promoting implementation of smart materials. On the other hand, holding specialized workshops and educational courses especially practical ones and giving license to consultant companies can promote knowledge of them and accompany them with updated technologies. Workshops can also be helpful for construction companies.

Therefore, for converting smart materials to the main option for designers in developing countries especially in Iran, it is necessary to provide essential contexts. The most important contexts that should be provided are to develop cognitions especially practical and applied ones and making culture of using such materials.

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