Improving Concept Learning in Green Building Education by Addressing Students' Learning Styles and Prior Knowledge

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Green building education is enhanced through close collaboration of students from different disciplines in order to solve challenging problems. Successful collaboration depends on the establishment of a common understanding of green building subjects among those involved. To gain this common understanding concept learning is critical. A concept learning process can be improved when factors affecting it are addressed. Prior knowledge and learning styles of the students influence the way they learn concepts. This paper discusses the relationship between the concept learning process and the prior knowledge and learning styles. An experiment was conducted by comparing two groups of students. One group learned concepts by using a conventional method, and the other group was given concepts customized to their prior knowledge and learning styles. Improvements in concept learning were measured through a series of tests. Tests results were analyzed using an independent t-test. The results indicated that the group which was given the customized material showed greater improvement in their concept learning than the group who learned concepts presented conventionally.

Key Words: Collaboration, Concept Learning, Prior Knowledge, Learning styles, Green Building.

Introduction

Integration of knowledge from different disciplines is often required to resolve unique and complex interdisciplinary problems such as those in green building. Interdisciplinary work typically integrates methods and concepts of multiple disciplines to create new knowledge (Borrego, 2007). Learning concepts from different disciplines has become an important factor to be considered in many professional and educational sectors including the AEC (Architecture Engineering Construction) industry that strives for the development and implementation of new technology for solving complex problems in the real world. This can be observed in the green building educational sector when students from different disciplines are involved.

Although many studies have pointed out that communication and sharing knowledge helps the process of developing such a common understanding, learning is an individual process. Different disciplines promote different learning styles. During the process of teamwork, the learning demands of each individual needs to be addressed. The way in which information is communicated to each individual is important, because the reception of information by each student may not be effective if information is not presented in the student's learning style. As per Corbett and Smith (1984), "The purpose of learning style analysis is to identify student strategies for learning and to wed them with instructional or training materials, experiences, instruction, and methods that foster a high rate of return – efficient, lasting achievement within a logical amount of time."

Students in the AEC domain come from different disciplines and may have different perceptions of concepts in the domain. In the green building education, students work collaboratively in order to attain the knowledge of concepts pertaining to it. Student collaboration involves the interaction among students of construction, architectural, mechanical, structural and other disciplines. Collaboration among the multidisciplinary students can be successfully achieved if they are knowledgeable about concepts involved in the different disciplines. The concepts students have in their minds impact the way they learn new concepts. Students can develop a new knowledge structure based on their prior knowledge. Roschelle (1995) described in his paper that "educators often focus on the ideas that they want their audience to have, but research has shown that a learner's prior knowledge often confounds an educator's best efforts to deliver ideas accurately. Prior knowledge can be at odds with the presented material, and consequently, learners will distort presented material. Neglect of prior knowledge can result in the audience learning something opposed to the educator's intentions, no matter how well those intentions are executed in an exhibit, book, or lecture." Thus, there is a need to better understand the relationship between effective concept learning in multidisciplinary studies, impact of learning styles and background knowledge. It is a challenging task to create an environment keeping all these aspects in mind.

Statement of Problem

Many studies have been focused on developing multidisciplinary courses to help students learn how to work effectively in a multidisciplinary team environment. One of the problems related to multidisciplinary learning is that students have different learning styles and prior knowledge. So, the challenge is to create an effective learning environment which caters to the individual's innate learning style and prior knowledge.

Literature Review

Prior knowledge of the students can be identified with the help of concept maps. Concept maps were developed in 1972 by Joseph D. Novak (based on Ausbel's work on meaningful learning) in his research program at Cornell University (Novak, 1998). A student's concept map can be compared with an expert concept map, a map prepared by an individual who is an expert in a particular field. By comparing the student's map with the expert map, the concepts that are missing in the student's map can be identified. Concept maps may help in bridging the gaps between disciplines and bringing individuals to a common understanding of the subject matter (Sims-Knight, 2004). Concept mapping is a knowledge representation tool, which has the ability to delve into a learner's cognitive structure and shows both the learner and the teacher what the learner already knows (Novak and Gowin, 1984). Concept maps are composed of concepts and their relationships, where two or more concepts are related with a linking word.

Concept mapping can be used as an assessment tool for teaching and learning, as it can measure the student's level of knowledge. There are two concept mapping techniques; one is the construct-a-map approach and other is the fill-in-the map approach (Primo et al., 1998). The construct-a-map technique depends on the number of concepts and/or linking words provided by an instructor. The scoring system for this technique is complicated as each student draws a different map; the scoring is based on counting the number of nodes, and linking lines to evaluate the accuracy of the map. The fill-in-the map technique provides students with a concept map where either the concepts or the linking words are left out. The students are asked to fill the blanks in the map. The problem associated with this technique is the structure of the map is predefined, and it is difficult to predict the student's existing knowledge as students have to fill-in the blanks given by the instructor. As per Novak and Govin (1984) concept maps can be scored by assigning points to the valid propositions, levels of hierarchy, number of branchings, crosslinks and examples. There are problems associated with the assessment and scoring techniques of concept maps. Assessment tasks not only elicit but also influence student's responses. The characteristics of the assessment tasks may make students respond in ways that are not relevant, such as guessing the concepts and their relationships. It fails in tapping the knowledge structure of the student. The problem with the scoring system is that it cannot capture information about the quality of student's responses (Primo, 2004).

After identifying the prior knowledge of the student with the concept maps, it is important to address the student's learning style. Students perform better in environments and with approaches that complement their learning styles than in environments that do not support their learning styles (Dunn et al., 1989). There are 71 taxonomies of learning styles (Coeffield et al., 2004). Effective pedagogy must employ a multitude of modalities that addresses various learning styles and preferences. Felder and Silverman's (1988) research on learning and teaching styles in engineering education introduces the index of learning styles. Many or most engineering students are visual, sensing, inductive, and active learners, and some of the most creative students are global learners. Most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential. These mismatches lead to poor student performance, professorial frustration, and a loss of many potentially excellent engineers to the society. Among the different theories VAK (Visual, Auditory and Kinesthetic) model is a widely known theory. Researchers in the field of education largely agree that people prefer learning new information in one of the three primary ways: seeing, hearing and experiencing (Lovelace, 2005). Visual learners learn by seeing, auditory learners learn by listening and kinesthetic learners learn by doing. Multimodal learners are those who use all the modes of learning. Some critiques of learning style models say that "Knowing one's learning style does not improve learning." According to Fleming (2006), "Knowing one's learning style can be beneficial if learners take the next step, and consider how and when they learn, as part of a reflective, metacognitive process, with action to follow. You don't fully understand how you learn with a learning style inventory alone. What happens afterwards has the potential to make a difference." VARK model was introduced by Fleming in 2001 (2008). His experience of working with students and teachers (9000 classes) for several years made him come up with the VARK learning style model. A VARK (Visual, Auditory, Reading, Kinesthetic) questionnaire prepared by Fleming and Mills (1992) helps in understanding an individual's learning style and in measuring direct instructional attributes. The Fleming-Mills learning style inventory is related to several other learning style instruments such as Kolb's Learning Style Inventory (LSI) and Myers-Briggs type indicator (Nefstead, 1998). Among all the learning style models described above, VAK/VARK model has proved to have more similarities with other models and this model can be implemented in order to understand the learning styles of students. VARK model has a strong research base, and proved to be successful when implemented on the students in many schools in the United States (Fleming, 2008).

Objective

The objective of the research is to better understand the relationship between students' concept learning in green building and the learning materials that are tailored to students' learning styles and prior knowledge.

Methodology and Hypothesis

The research was aimed at answering the following question: Does addressing and supporting students' prior knowledge and learning styles help in improving concept learning? The experimental population was composed of students from multidisciplinary backgrounds. Forty students were divided into two groups (A and B) of 20 students each. Group A is the "Treatment Group" and group B is the "Control Group." The population undergoing experiment was measured by μ which is the mean score representing the accuracy of student's knowledge of a concept. Treatment group's scores were measured by the statistical variable μ_a. They learned a set of concepts related to green building with learning materials prepared by the researcher. Control group's scores were measured by the variable μ_b. They learned the same concepts in the conventional format, e.g., text books or notes. The research hypothesis is denoted by H_1 and the null hypothesis is denoted by H_0.

H_1: The students who gain the knowledge with the concepts tailored to their learning style will learn better than the students who learn in the conventional method.

H_0: The students who gain the knowledge with the concepts tailored to their learning style will learn the same as the students who learn in the conventional method.

The study hypothesizes that, H_1: $\mu_a > \mu_b$ and H_0: $\mu_a = \mu_b$.

Research Process

In order to perform the study, a test was designed and conducted on a group of graduate students in construction management at Florida International University. Forty graduate students taking BCN 5728 (Principles of Construction Scheduling) course were tested. The students in the class were from different undergraduate disciplines, including architecture (12 students), civil (11 students), mechanical (2 students), construction (3 students) and others (business management, law, psychology, biology and chemistry – 12 students). Collaboration in this diverse environment is slightly time taking and difficult as their prior knowledge influences the current concept learning process. Since their undergraduate degrees vary, each student may have a different perception of green building concepts. All these aspects were addressed when the test was designed. Treatment group followed the designed method and control group followed the conventional method. Conventional method is the typical pedagogical way, in which concept learning takes place irrespective of the student's background knowledge and learning style. The learning environment was in the form of lectures in a classroom. Materials such as textbooks or notes assigned by the researcher were presented to the students and their understanding to a specific set of concepts was tested accordingly by using test methods such as multiple choice questions. In the designed method the student's learning styles and prior knowledge were considered and the study materials were customized accordingly. The comparison was between the performance of both the groups, which will lead either in accepting or rejecting the hypothesis.

The test was performed by selecting the concepts of "Structural Insulated Panels (SIPs)." Structural insulated panels are energy efficient and are used for exterior building envelops. The whole study revolves around different concepts (architectural, construction, structural and mechanical) related to SIPs. Initially an expert concept map was prepared. The expert map was prepared in order to check the concepts that students miss when the prior knowledge and final tests were conducted. Students were not asked to draw a concept map as there are limitations associated with the two concept mapping techniques (construct-a-map and fill-in the map). If the students are asked to construct a map then students prepare it based on their prior knowledge. Since prior knowledge varies from student to student there will be a wide variation in the concept maps. Few students may select a set of concepts with which they are familiar, and draw a map; others may include all the concepts in their map giving a chance to their luck (doing guess work). The results may mislead the instructor. There will be a wide variation in each student's map, which was observed when thirty graduate students were given twenty-five green building concepts on "Levelized Cost of Energy" to draw a concept map. Some students selected one to ten concepts from the list and others selected all the concepts even though they are not familiar with them. Some had difficulty drawing the map itself. Thus, the tests on the concepts of SIPs were analyzed by comparing the students' answers with the concepts in the expert concept map.

The research was conducted in four different stages. The ***first stage*** helped in understanding the prior knowledge of the students. SIPs have concepts, which are related to architecture, structural, construction and mechanical fields. Concept maps can be used to check the knowledge that students bear. Concepts from each discipline were color coded in the expert concept map. Color coding was done as the instructor can easily gauge the student's level of concept knowledge by seeing the missing colored concept. For example, grey color was allotted to a concept from mechanical disciple and blue color was allotted to an architectural concept. If a student is missing the grey color concept in the map then it is very easy for the evaluator to judge. The evaluation of the student's knowledge about the other disciples becomes easy if the concepts are color coded according to disciplines. A multiple choice test was formulated based on some very basic concepts from the expert's concept map. The test scores were not graded with 100 points as maximum. The prior knowledge test had 20 questions and it was graded for 20 as the maximum score. This test was given to the students in order to check their existing knowledge of green building concepts. The purpose of including these questions in the prior knowledge test was to identify the conceptual knowledge of students from varied backgrounds (undergraduate education). Sometimes if the students have no previous knowledge on a particular concept they may tend to answer something which they might feel is correct. This will mislead the instructor. So, each question was provided with an option "No idea" in order to get the exact answer. Evaluation of the prior knowledge test helped in identifying the student's level of knowledge on the concepts of SIPs.

Example of a question given in the tests (prior knowledge and final):

Q. What is Life Cycle Cost? (Mark all that apply)

☐ Have initial costs, financing costs, operational costs
☐ Is the total cost of construction
☐ Treats design decision as investments
☐ No idea

The ***second stage*** was to understand the learning style of each student. The learning style of each student was checked as they have an aptitude to learn well if concepts are constructed according to their learning styles. A visual, auditory and kinesthetic questionnaire prepared by Neil Fleming was administered in order to check the learning style of students. This questionnaire has general questions about how individuals perform activities in their daily life. While administering the questionnaire only the visual, auditory and kinesthetic elements were considered and the reading/writing was not considered. The reading element was not included as it has been considered as a part of visual category based on the literature study. Among the different types, visual learners occupied the major percentage of the class (Figure 1). Figure 1 shows the percentage of each type of learner.

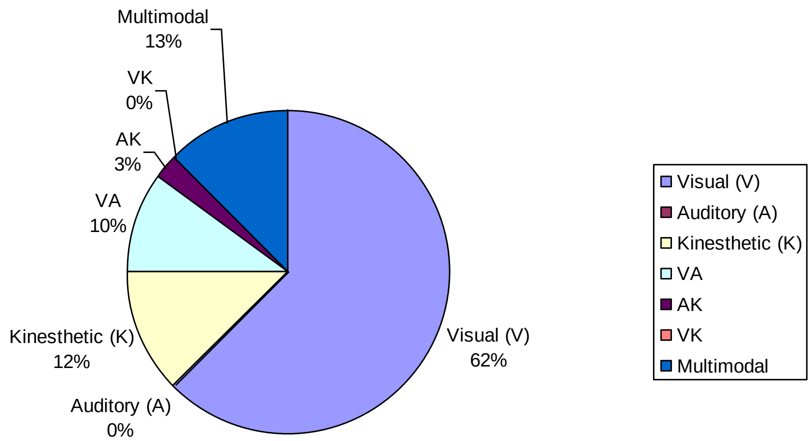

Figure 1: Pie Chart showing the different types of learners in BCN 5728 class

The ***third stage*** was designed based on the first two stages. Here, the materials were designed according to their learning styles and prior knowledge. After knowing the percentage of students with each learning style, materials were presented to them accordingly. Based on the students' prior knowledge each one of them was given a customized plan, which gives them the concepts they need to focus on. For example, if it was observed (from the prior knowledge test response) that a student had good knowledge of SIPs, then that student was given guidance such that the student learns only the missing concepts in the first test. The materials in stage III were tailored to the students' prior knowledge of SIPs. Students having zero prior knowledge on SIPs were guided to learn each and every concept in a planned manner. This guidance was given to students in both groups along with the materials. Students were then given twenty minutes to go through and understand all the concepts presented to them. The whole process was timed. An output can be compared and gauged correctly only if it happens in the allocated time. The speed of understanding and the accurateness of perception can be measured if the learning process is timed.

The groups were formed such that there were 13 visual learners in treatment group and 12 visual learners in control group. The remaining types of learners were divided among the two groups. Visual learners in treatment group were given visual materials and visual learners in control group were given non visual (conventional) materials. Students who had kinesthetic and multimodal learning styles were also divided among the two groups. The students were divided such that there were equal numbers of visual and other types. The test was conducted such that one group of visual learners was given visual materials and the other group of visual learners was given non visual (conventional) materials. This was to determine whether visual materials helped visual learners or not. The differences in the final scores and the improvement of concept learning from the prior knowledge for visual learners in both the groups were compared. Similarly, other types (kinesthetic and multimodal) of learners were asked to learn visual and conventional materials.

All the concepts of SIPs were presented with the help of figures, images, graphs and concept maps for treatment group students. For example, figures helped in showing the structural composition of SIPs (Figure 2). Some part of the materials was visually represented and the remaining part was explained with the help of concept maps which is a graphical tool for representing concepts. The major and important part of the materials was initially explained with the concept maps. Later, each part was explained with images/figures. Since concept maps help in depicting the concepts with the relations among them, it makes a student easy to understand how the different concepts are related to each other apart from the meaning of each concept. The information on SIPs was divided into different categories (general, structural, design, construction and mechanical aspects) focusing on the concepts coming from different disciplines involved in it. The study materials were prepared in Microsoft FrontPage and presented to the students. Control group was presented with the same information put in a conventional format. Handouts having information on SIPs were distributed to the 20 students in this group. Students have to read the whole handout in order to understand the concepts of SIPs. Though the information given to both the groups was the same, the presentation and depiction of concepts was completely different. For treatment group, all the concepts were made more visual. Some concepts which cannot be depicted with the concept maps or images were explained with text supported by a relevant figure. Figure 2 is an example of the material presented to the treatment group on "structural properties of SIP." The same was given to group B in conventional method (two paragraphs of written text and a supportive figure if required).

The ***fourth stage*** evaluated the improvement of concept learning and tested the hypothesis. A final test was conducted in order to determine the development in the student concept learning process. While testing, it was observed that control group students took longer time to answer the questions than treatment group. The test had multiple choices, true/false and fill-in-the-blank questions. The final test had 26 questions and was graded for 26 as the maximum score. A few questions from the prior knowledge test were repeated in the final test to see if students improved their knowledge after reading the presented materials. The evaluation of the test results helped in understanding whether the students from different disciplinary backgrounds were able to understand the green building concepts and reach a common understanding. In addition, a survey was conducted in order to know if the study materials given were easy for them to learn and if they were willing to learn the material customized to their preferred learning styles.

In order to test the hypothesis, the evaluation was planned in three different methods. In the first evaluation process (Test 1), the difference in the scores of the prior knowledge test and the final test were summarized. By this one can understand which group had more improvement in their concept learning when prior knowledge is addressed. Test 1 compared the scores of the students' concept learning from the prior knowledge test through the final test (from Stage I through Stage IV) for both the groups (while addressing the learning styles). Initially the prior knowledge test for both the groups was scored. Later after going through the whole process the final test was also scored. The difference of both the scores (final score and prior knowledge score) was considered and the mean was calculated in order to see the improvement of both the groups. That is, improvement in concept learning is equal to the difference between the final test score and prior knowledge test score.

The second evaluation process (Test 2) focused on the material presented to both the groups. It answered questions such as – "What is the score when some part of the materials presented to them is similar in both cases?" and "What is the score when some part of the materials presented to them is completely different in both cases?" This is to observe how both groups performed when the medium and method of material presentation was different. Test 2 analyzed the differences in the scores when the learning materials were presented to the same group in two different ways. The materials presented to the groups were divided into two parts. One part of the materials presented to both the groups was similar and the other part of the materials was different. So the questions based on both the parts were segregated and scored. The variation in the results of both the groups was studied and analyzed with a t-test. The *Dif_Mat_Score* in group statistics and the independent sample test refers to the difference of *similar materials* and *different materials*. That is, *Dif_Mat_Score* is equal to the difference of *Similar Materials* and *Different Materials*. Different materials mean that treatment group and control group had different content which had the same meaning that was presented differently. Same materials mean that both the groups had same materials which were presented almost similarly.

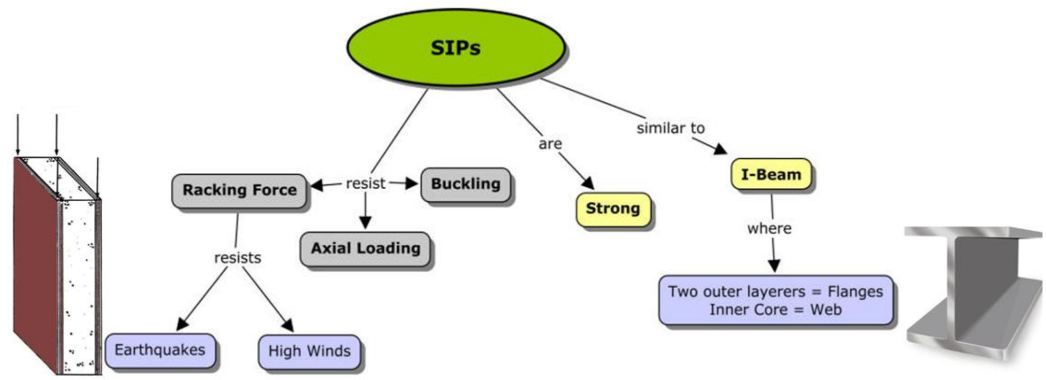

Figure 2: Presentation of concepts of the "Structural Properties of SIPs" for treatment group

The third evaluation process (Test 3) focused on specific questions given in the final test. Some study materials are bound to be presented either in text or through images irrespective of the group or type of learners. In such cases the variation in the scores for both the groups was observed. Q1, Q2 and Q3 (Table 1 & 2) refers to the three questions which were selected for analysis.

Analysis and Results

A statistical analysis was done in order to analyze the performance in the test. The statistical procedure that was used is the student's t-test. T-test is the most appropriate among all because it is used when the comparison is between two independent sample means which are made up of different groups of individuals. One-tailed t-test was performed to analyze the data.

Table 1

Group statistics for tests 1, 2 and 3

		Group	N	Mean	Std. Deviation	Std. Error Mean
TEST 1	Difference_Score	1 Group A	13	55.5954	20.10894	5.57722
		2 Group B	10	37.921	14.6941	4.64668
TEST 2	Dif_Mat_Score	1 Group A	13	-5.1531	10.70505	2.96905
		2 Group B	10	8.665	7.99979	2.52976
TEST 3	Q1	1 Group A	13	69.23	48.04	13.32
		2 Group B	10	30.00	48.31	15.28
	Q2	1 Group A	13	84.62	37.55	10.42
		2 Group B	10	40.00	51.64	16.33
	Q3	1 Group A	13	53.85	51.89	14.39
		2 Group B	10	30.00	48.31	15.28

Table 2

Independent samples test for tests 1, 2 and 3

			t-test for Equality of Means		
			t	**df**	**Sig. (1-tailed)**
			Lower	**Upper**	**Lower**
TEST 1	Difference _Score	Equal variances assumed	2.336	21	0.014
		Equal variances not assumed	2.435	20.97	0.012
TEST 2	Dif_Mat_Score	Equal variances assumed	-3.408	21	0.0015
		Equal variances not assumed	-3.543	20.99	0.001
TEST 3	Q1	Equal variances assumed	1.937	21	0.033
		Equal variances not assumed	1.935	19.457	0.034
	Q2	Equal variances assumed	2.403	21	0.013
		Equal variances not assumed	2.303	15.845	0.017
	Q3	Equal variances assumed	1.125	21	0.136
		Equal variances not assumed	1.136	20.157	0.134

There were 40 students in the prior knowledge test but the number of students reduced to 23 when it came to the final test. The test was conducted with 13 students in the treatment group and 10 students in the control group. The analyses of the three tests (Test 1, Test 2 and Test 3) are shown in Table 1 and Table 2. In Tables 1 and 2, Difference_Score refers to the improvement in concept learning from the prior knowledge stage through the final stage. It was calculated as the difference between the final test score and the prior knowledge test score. Similarly Diff_Mat_Score in both the tables refers to the difference of *similar materials* and *different materials.* The negative mean value of treatment group for Test 2 (Table 1) reflects the higher score in different materials (since Dif_Mat_Score = Similar Materials – Different Materials). Treatment group did well in the different materials part. Control group positive mean reflects a higher score in the similar materials part. Thus, it shows that the different materials (i.e., completely visual for treatment group and conventional for control group) presented to the group makes a difference. Treatment group scored higher than control group. Table 1 shows higher mean values for treatment group in all the three tests. Q1, Q2 and Q3 in Table 1 and 2 refers to question 1, question 2 and question 3. Table 2 shows a significant difference between the two groups in tests 1 and 2. In test 3 significant difference was observed only in Q2. After observing a significant difference between the two groups and seeing their means in Table 1 we can say that treatment group performed well than control group. Thus, concept learning process can be improved if the learning styles and prior knowledge of the students are addressed.

Conclusions and Further Work

This work dealt with the students' concept learning process and the factors influencing it. In the course of this work previous literature was examined and aspects such as concept mapping, prior knowledge and learning style theories were discussed in detail. Green building has concepts from different disciplines and it is difficult for the students in a multidisciplinary setting to understand them. Addressing prior knowledge and learning styles while teaching concepts is important because a successful collaborative output can be observed if every student involved has a common understanding. A group of students were tested by giving study materials tailored to their learning styles and prior knowledge. Upon the analysis of the t-test which was considered in three different perspectives it has been proved that there is a significant difference between them and their means indicated that treatment group's performance is better than control group's performance. The results of the tests rejected the null hypothesis (H_0: $\mu_a = \mu_b$) by showing that addressing prior knowledge and learning styles of the students will help them learn concepts better. In conclusion, giving importance and addressing a student's prior knowledge and learning style will support the concept learning process of a green building.

Further study can be focused on concept presentation methods. There are both abstract and concrete concepts. The concepts of green building – structural insulated panels (SIPs) are concrete, they can be represented without much difficulty (with images, figures and concept maps). However, there are some concepts which cannot be shown in a concrete manner; they are called the abstract concepts. The study did not give a solution for presenting abstract concepts in visually rich representations. Methods of representing the abstract concepts to the students are yet to be studied. Test-retest statistical method was not conducted here. The same test was not performed twice (at two different times) in order to observe the difference in the scores of both the groups.

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