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Rethinking Construction Pedagogy with Emphasis on 3D CAD and Simulation

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Abstract:

In present day's practices, architects have very less authority over construction. It is also observed that architects more often do not have the requisite construction expertise to contribute much in the construction phase of a project. Most of the times, it is the architecture schools which are blamed for not providing sufficient technical knowledge to the students. This might be because the schools mostly rely upon traditional teaching practices. But traditional lecture learning environments have been criticized as being not suited to all students and not developing the prerequisites for professional expertise; the emphasis mostly being given on information rather knowledge. Hence students find it difficult to understand and lack interest in learning such technical subjects. It is also observed that there is a lack of interactive environment in construction studios as against design studios which are mostly carried out in an informal and interactive environment.

Hence at our institute an experiment is carried out by using 3D CAD and simulation for explaining the technical aspects in a better manner. It was also realized that the model making exercise though an excellent three dimensional tool, is very time consuming. Hence such a tool was required which will explain the technical details in three dimension and at the same time prove time saving also. To overcome this problem, the teachers experimented with a new tool where computer animations are used for explaining complex topics. Our experiments demonstrate the viability of 3D modeling and construction simulation as a method of incorporating construction issues into studio courses. The creation of 3D models of details helps explain the technical aspects in a more powerful way than conventional 2D drawings on blackboard.

Apart from this, some innovative techniques like data sharing, exchange of information and social interaction using digital means are also experimented so as increase the level of interaction in construction studios amongst the teachers and students and their peer groups. Even though we have not evaluated the effectiveness of our teaching method statistically, the response from the students shows that our new teaching method using digital tools is effective enough to generate interest in the students towards learning technical subjects and supporting us in achieving our goal of improving student's knowledge of construction subject.

Keywords: Construction pedagogy, interactive environment, digital tools, 3D modeling and simulation

Introduction:

It is a general observation that students do not gain much practical knowledge of construction methods during their architectural education. In the past, architects often participated closely in construction supervision and observation more regularly. In contrast, the building industry has now a day's developed growing trend towards construction management and project management being treated as independent services from architecture. Architects often see this trend as a dilution of their power and influence. This is because in present practices architects have very less authority over construction. Owners feel that architects more often do not have the requisite construction expertise to contribute heavily in the construction phase of a project. For this trend, most of the times, the blame is laid upon the schools of architecture for not providing sufficient technical education. This is because faculty members tend to concentrate research and teaching upon design, aesthetics, theory and history. Due to this, students may complete their education lacking know-how in building technology and construction [1].

Karloff [2] has also noted the frequency of the criticism that recent graduates lack knowledge of construction. However, he defends the schools by suggesting that their mandate is not to provide narrow, practical training but instead to cultivate skills in life-long learning. In his view, rather than

relying upon the schools, practitioners should provide knowledge of construction to interns.

Traditional lecture learning environments have been criticized as being not suited to all students and not developing the prerequisites for professional expertise; the emphasis mostly being given on information rather than learning [3][4]. In practice, young professionals need the ability to analyze problems, to separate complex matters into sub-problems and to solve these problems without losing sight of the whole picture [5].

Whatever the merits of one side or the other in the debate, it is clear that increasing students' knowledge of construction is a desirable objective. In particular, knowledge of construction should be integrated into studio courses so that students gain the ability to apply the knowledge obtained in lecture and support courses [6]. According to Adele Naude Santos, biggest problem of architecture education continues to be the lack of integration of technical subjects with design studios, despite the fact that this fusion is essential to architectural thinking [7].

Indentifying the Problem:

Evaluations suggest that, within construction related professional courses, technical aspects are the most difficult to teach. This is particularly evident in the teaching of architecture students as many fail to make the link between construction technology and the main thrust of architectural education, the design studio [8]. This most of the times leads to lack of interest on the part of the students in learning technical aspects. Apart from this, students also find technical aspects difficult to understand and hence there are lot of mistakes in technical drawings also. As a result of this, the passing percentage of students in technical subjects is often less.

Right from past till date it is been observed that teaching construction technology is mostly dependent on traditional tools especially blackboard and in recent years power-point presentations to some extent. Moreover it has always been much instructor oriented encouraging very less interaction amongst the students and the tutor as against design studios. Traditionally the design studios are being carried out in a more informal way and occur in settings where students interact freely with their peers and design tutors as well. Apart from this design studios are more importantly dependent on the visual and graphical processes. In addition to this, a lot of hands on experience activities are also carried out in design studios.

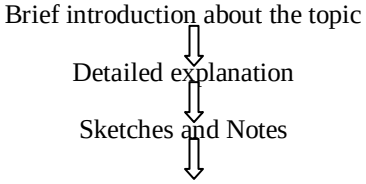
If design studio can be managed in a student centered and hands on environment, why can't courses in Construction technology / tectonics be delivered in a similar atmosphere [8]?

Looking to these challenges of lesser understanding of technical aspects in students, resulting mistakes in technical drawings and reduced interest in learning technical subjects, it was realized that there is a need to shift the pedagogical practices in tectonics by making teaching more interactive and more dependent on visual and graphical process for better understanding. To achieve this, innovative methods and ways were experimented in teaching construction subject.

In this paper an attempt has been made to document the teaching process carried out in third semester construction technology at Priyadarshini Institute of Architecture and Design Studies, Nagpur to make Construction teaching more interactive incorporating visual and graphical tools like 3D CAD and simulation. Such new pedagogical practices like 3D modeling and computer simulations may help encourage architecture students to learn more about the buildings construction.

METHODOLOGY OF TEACHING:

In order to find the solutions to the challenges listed above in construction teaching, it is realized that it is utmost important to give the students clear understanding about the technical aspects. At the same time, it is also necessary to ensure correctness of technical drawings drafted by the students and more importantly to generate interest in students about learning technical aspects. Hence an array of tools are utilized for making the students understand the subject which include both traditional practices like chalk and talk, giving notes and sketches and modern tools like documentation of site activities in the form of photographs and videos, use of three dimensional visual graphics, computer animations, etc. Hence following methodology was adopted for covering each topic while teaching:



Site Experience

⇩

Videos and photographs

⇩

Documentation of existing construction site

⇩

Sketching the whole drawing on blackboard

⇩

Model making

⇩

Using computer for 3D modeling and simulation

⇩

Drafting and submission of completed drawings

⇩

Comments and assessment of submitted drawings

1) Brief introduction about the topic:
While covering any topic, firstly a brief introduction about the topic is given explaining various terminologies, definitions and general idea about the topic.

2) Detailed Explanation:
After this, various presentations and lectures are given to the students for explaining the topic in depth. In topic like R.C.C, special emphasis is given on compression and tension areas and placement of reinforcement accordingly. For this purpose, tools like power-point presentations, chalk and talk etc. are utilized.

3) Sketches and Notes:
While giving the presentations and lectures, students are asked to write down notes as well as sketches in a separate journal provided by the institute

4) Site Experience:
Experience on the site has proven to be very useful and should be encouraged in architectural education. especially towards the understanding of technical subjects such as construction technology. The advantages are numerous. For example, it helps the students understand the subject better by observing and experiencing the actual project being carried out. In addition, the students will also experience and understand the fundamental characteristics of building materials like wood, masonry, steel, concrete and other finishing materials. But the main drawback of this method is that it is very expensive and time consuming [9]. Keeping this in mind, the students are taken to site visits wherever possible so as to have clear understanding about the technical aspects (Image 1).

Image 1: Site visit

5) Videos and photographs:
In third semester, major part of the syllabus talks about reinforced cement concrete. For such topics, it is dangerous to take large batch of students to the site where R.C.C. work is going on. Moreover it is practically very difficult and time consuming to take the students to the site at every stage of construction. To overcome this problem, major R.C.C. part is explained to them through video clippings and photographs of execution of on-site work.

Detailed documentation of construction site:
For the same, teachers selected a live site where construction work is going on for documenting the construction activities. Images and video clippings at every stage right from foundation to finishing stage are clicked by the faculty (Image 2) which are shown to the students at respective stages.

Image 2: Sequence of foundation casting on site.

6) Explanation by sketching the whole drawing on blackboard:

Before drafting actual sheet by the students, the whole drawing is drawn on the blackboard by the teachers (Image 3, 4) and students are supposed to sketch the whole drawing in the sketch book. This proves very beneficial in two ways. Firstly, it helps the teachers explain the technical aspects in a better manner so as to increase the level of understanding of the students. Apart from this, prior sketching activity makes the drafting easier for the students.

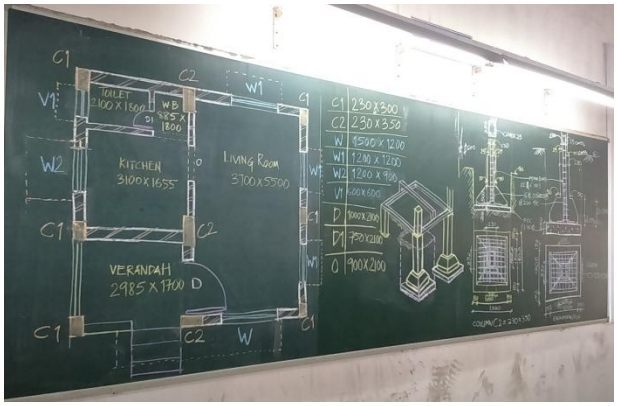


Image 3: Sketches drawn on blackboard

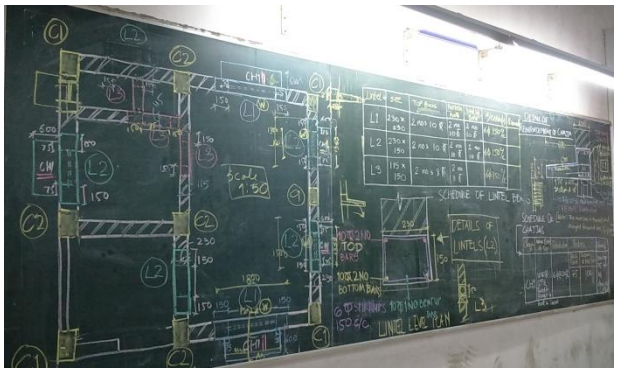


Image 4: Sketches drawn on blackboard

7) Model making:

It is a very common experience that students are more motivated and work much harder with the problem based learning model than with traditional teaching methods [10]. John Dewey, educational pragmatism, supported the *"learning by doing"* approach to education as far back as the early 1900's [11]. It is essential that architectural engineering students develop both quantitative and qualitative understanding of engineering concepts and principles. Small-scale modeling provides students with opportunities to discover that learning structural engineering principles can be an enjoyable experience that leaves a stronger impression for longer retention [12].

Keeping this in mind, students are assigned with the task of preparing the models of various building components (Image 5, 6, 7). Models being three dimensional, it helps students in better understanding of the structural system

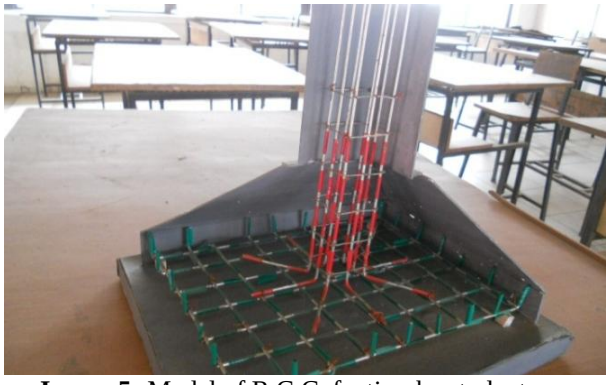


Image 5: Model of R.C.C. footing by students

Image 6: Model of R.C.C. beam by students

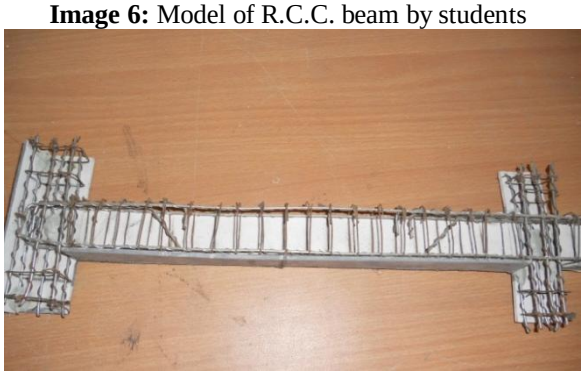


Image 7: Model of R.C.C. Beam by students

8) Using computer for 3D modeling and simulation:

It is realized that the model making exercise though an excellent three dimensional tool, is very time consuming. Hence such a tool was required which will explain the technical details in three dimension and at the same time prove time saving also. To overcome this problem, the teachers experimented with a new tool of using computer animations for complex topics so as to demonstrate the viability of 3D modeling and construction simulation as a method of addressing to technical issues in construction studios. Creation of 3D models of building components helps explain the technical aspects in a more powerful way than conventional 2D drawings on blackboard.

Construction animation graphically illustrates construction process, sequence, and issues of form work and temporary structures It can grab students' interest and make them aware of the construction aspects of architecture [6].

Our initiative:

Computer has proven its capability in teaching and learning process. Most of the times, faculty uses computers for preparing power point presentations and slide shows. We tried to take this teaching experience to next level by using 3D CAD simulations and modifying the method and practice of teaching architecture, especially construction.

We start with simple RCC framed structure which includes all the elements from foundation, columns, plinth beams, lintels, slab beams and one way and two slabs with staircase. Next level is explaining role of each element in transferring the load of building to the ground. Concept of compression and tension is most important to understand as it is the base of any structural system.

Here example of continuous beam has been used to explain the concept. Following images (Image 8 and 9) explain how beam reacts at support and mid-span. This simulation helps students to understand the effect of column support on horizontal beam and how bent up bars and extra top bars prevent the system from failing. Once students are clear with the concept of compression and tension, they can easily understand the placement of reinforcement in relation to it.

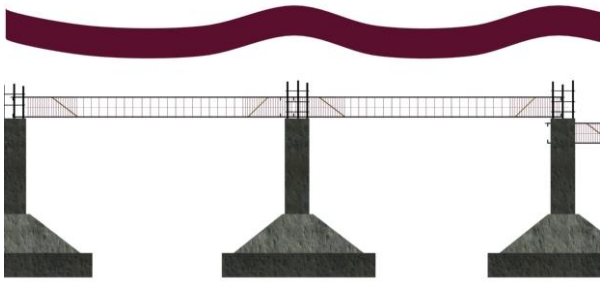


Image 8: Computer graphics showing continuous beam and its behaviour

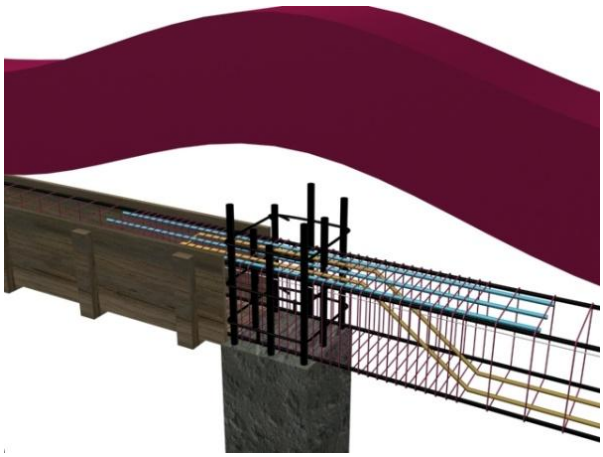


Image 9: Computer graphics showing behavior of continuous beam at support

Detailed solid modeling in CAD software of the same structure is executed. Today's generation of students being techno savvy, easily understands the language of visual / graphics, 3D modeling and computer simulations which strengthen their understanding and creates interest in subject, that encourages students to learn relation between construction and design of buildings. Moreover watching 3D graphics, moving objects in animation is always a fun while learning. All 3D models are done in real-time proportion so students get exact idea of scale. New angles of viewing are created with camera positions which are not possible even on site, which gives in depth knowledge (Image10).

Use of texture and materials along with light and shadow effects in 3D simulation gives realistic effects, so students can directly relate it with site conditions. Colour coding of all the steel bars is kept same in all RCC elements to avoid confusion (Image 11).

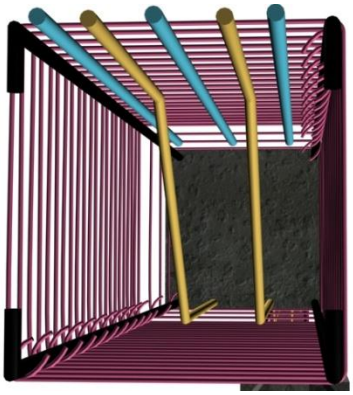


Image 10: Inner view of beam reinforcement

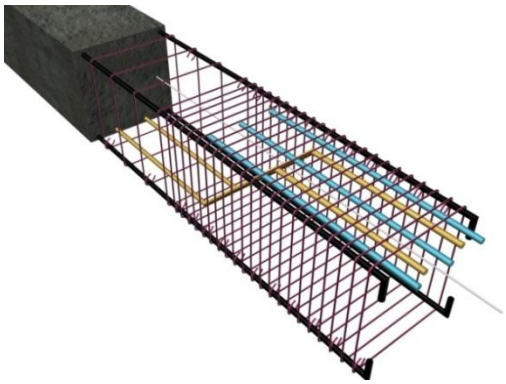


Image 11: Use of texture depicting materials and colour coding of bars for better understanding

Sequence of images derived from 3D CAD models are shown in Image 12, objective being explaining students about assembly of different types of steel and their position in RCC elements.

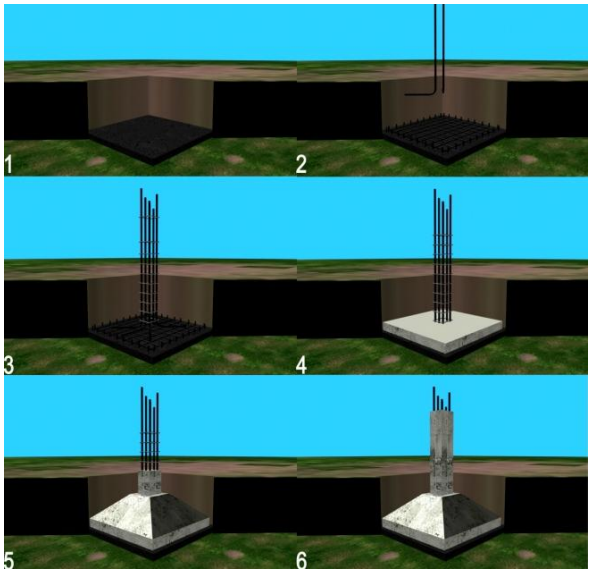


Image 12: Images showing stage-wise activities in casting foundation

9) Drafting the drawings:
While drafting the drawings, discussions are carried out with students individually and in groups also on the drawing board explaining the details and pointing out the mistakes.

10) Comments and assessment of submitted drawings:
After the drafting is complete, the students submit the drawings. In order to ensure the correctness of drawing the submitted drawings are corrected and assessed in front of the students. Mistakes are pointed out and comments and remarks are written on each and every drawing submitted. (Image 13, 14, 15).

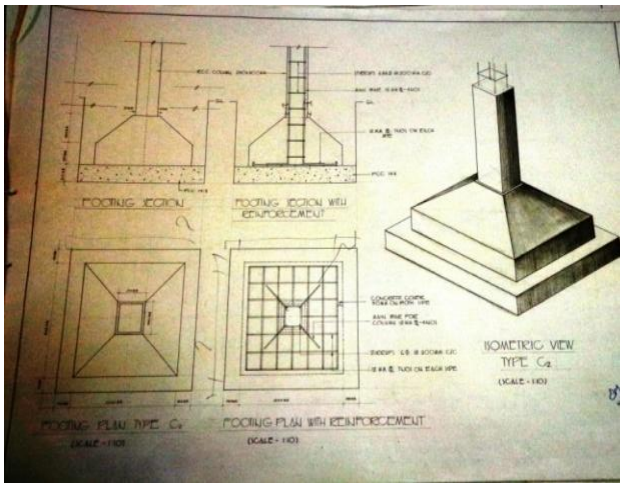


Image 13: Drawing drafted by students

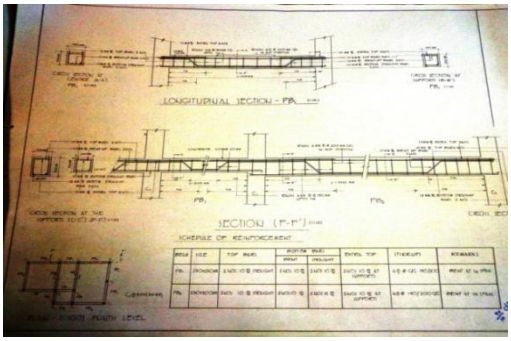


Image 14: Drawing drafted by students

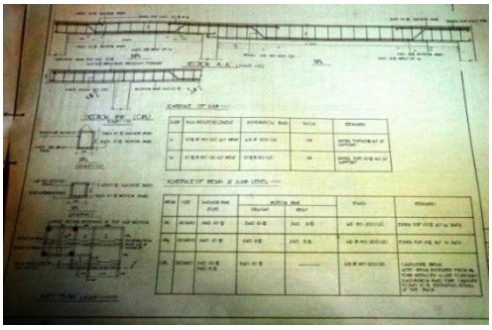


Image 15: Drawing drafted by students

PROCESS OF TEACHING:

A) Levels of Explanation:

Thus the whole process of explaining the topic is divided into seven levels:

1st level: General explanation about the topic

2nd level: Detailed explanation through power point presentations, notes, sketches, etc.

3rdlevel: Explanation through site visit/site documentation

4th level : Explanation and clarification on blackboard in the studios

5th level : Explanation through 3D graphics and animation

6th level : Explanation and clarification in group of students on sketch book also giving tips on how to draft the drawing

7th level : Explanation and clarification to individual student on drawing board

B) Teaching Process for Individual Lecture:

i) Theory Class:

While introducing any topic, major thrust is given on making the classes more interactive by involving the students in discussions so that they should not get bored up with the theory and be attentive in the class at the same time. Initially the students are asked about their own ideas, knowledge or information about that particular topic which is in the form of short question and answer session. Sometimes students are also called to draw some sketches related to the topic studied in the previous semesters on blackboard. This helps in understanding the student's own knowledge about that topic in general. It also facilitates in knowing the depth required for explaining that particular topic and details required while clearing various aspects. Then the whole topic is explained in depth with the help of power point presentations, 3D graphics and animation as well as drawing sketches on blackboard. While giving the presentations, the students are simultaneously asked to take down the notes and sketches. After explanation, the students are asked whether they have any doubts and if any, they are cleared up.

ii) Drafting Studio Class:

Before starting the drafting of drawings, the whole drawing is drawn and explained on the blackboard along with the schedule of reinforcement, sections, details, etc. Instructions and suggestions are also given to individual student on drawing board. While drafting, much emphasis is given on method of dimensioning, specifying materials, types and sizes of various elements. After drafting the students submit the drawings which are then corrected and returned to the students.

Observation:

With the best possible efforts and an attempt to ensure correctness and timely completion of submissions, the actual result and response from the students is good. After pointing out the mistakes and giving the comments, most of the students complied and corrected the drawings. This also resulted in improvement in the university exam results in construction subject.

Major problem is with submission of assigned task on scheduled date and time. This happens because students are somewhat reluctant in drafting the drawings in the class and prefer to draft the drawings at home. Reason could be that the students find technical aspects difficult to understand which results in lack of interest in drafting the technical drawings. Another reason could be that there is workload of other subjects because of which the drafting of drawing gets delayed resulting in failure in submission on given date.

This problem is tackled by sticking to the schedule of submission and assessment by the students and teachers as well. It is also realized that if the drawing is completed in the studio class itself, there will not be any delay in submission of completed drawing. This resulted in improvement in timely submission done in class.

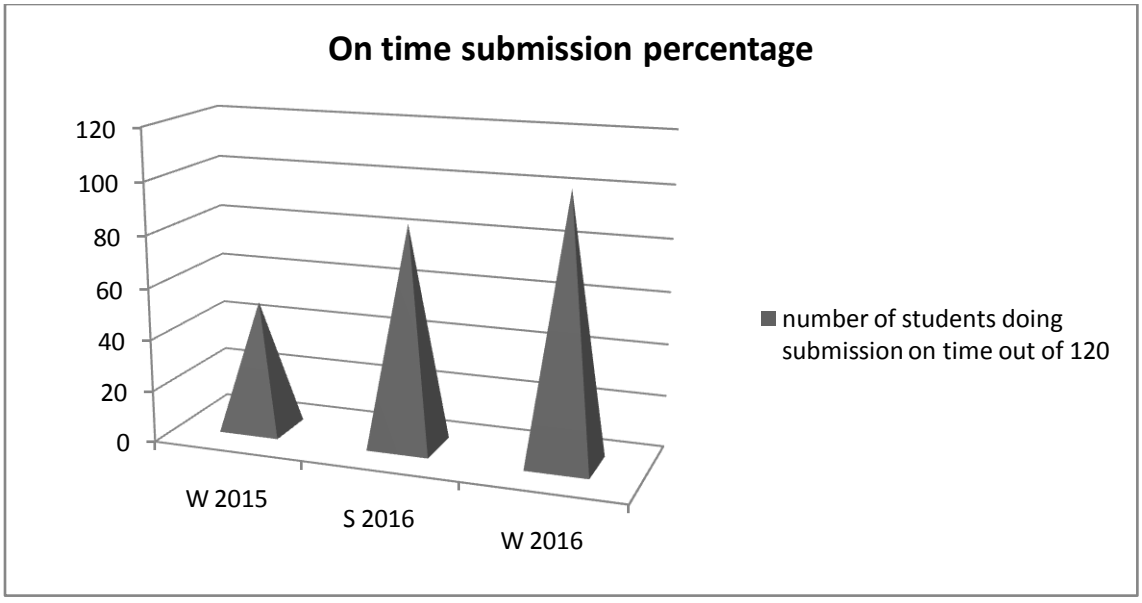


Table 1: Table showing on time submission done by the students

Measures for generating interest amongst the students in learning technical subjects:

It could be done by motivating the students and developing interest amongst them towards learning technical subjects like construction in following ways:

1) Creation of socially interactive learning environment:

Seating arrangement for drafting studios can be done in a way which will encourage interaction of students amongst each other. Drafting tables can be arranged in a group of 3 or 4 students.

2) Extensive use of following aids:

- Digital resources
- Data sharing and exchange of information
- Social interaction through digital means

3) Online forum participation by students and teachers:

This forum will not only help the instructors to interact more with the students but also facilitate a holistic understanding of student's views about the ongoing coursework.

- Students can ask queries or doubts at any time.
- Students and faculty members can exchange relevant images, videos regarding upcoming technology apart from the curriculum.
- They can carry out discussions online.
- It will also help teachers in posting announcements collectively for all regarding dates of submission, topics to be covered in the coming lectures, etc.
- An online group can be formed called "Construction forum". This will help in communicating with instructors and peers outside regular class hours.
- Most importantly it will help in increasing interaction between teachers and students and amongst students as well.

Conclusion:

Lectures are often one-way communication. Generally, the lecturer gives a monologue of the message he is set to convey. Discussion, when there is one is normally carried out at the end of the period. It is, however, too little to the immense amounts of syllabus to cover within a certain predetermined time [9]. Hence making the classes interactive is utmost important so that students should develop a sense of participation in the process of teaching and learning and move way from hesitation and ask his doubts freely in the class and get involved in the discussions. Here also technology can play a vital role in the form of teaching tools like digital resources, data sharing, social interaction and exchange of information.

For a meaningful and effective learning experience, three vital ingredients are essential, prior knowledge (the experience) of the students, the teaching methods employed and the learning methods adopted by the students. This paper attempted to investigate these three components amongst architectural students and teachers.

The rapid development of modern construction and material technology greatly influences the way students think and design. Their exposure to the modem building forms and available information from the internet, television, magazines, etc. influence these students to design complex

building forms for example, following the ideas from famous architects like Frank Gehry, Norman Foster and many others, whose designs use most advanced technology of construction and materials. The schools should be fully aware of these changes required by the students, unfortunately, the syllabus has remained unchanged for years and does not incorporate the latest developments [9].

The potential of digital media in architecture can be seen in many ways, in the design studio as well as in technical subjects. Computer Aided Design or Drafting (CAD) can prove an important tool for the tutors as well as the students making teaching and learning more effective. This leads to greater learner satisfaction and also has an extra advantage of being able to match the student's learning style as students being much techno-savvy right from childhood in todays modern world. Hence it can be projected as being the solution to problems faced by teachers at many levels. It also can effectively address to the problems of large classes and limited time for individual instruction. Technology based teaching can increase understanding of technical aspects in architectural education. Use of digital resources can prove to be a viable way to respond to industry demands for increased knowledge of construction among architecture students.

Even though we have not evaluated the effectiveness of our teaching method statistically, the response from the students shows that our new teaching method using digital tools is effective enough to generate interest in the students towards learning technical subjects and supporting us in achieving our goal of improving student's knowledge of construction subject.

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