

Optimal method for teaching concrete technology for civil engineering students

Abstract

The paper summarizes the methods that are used in teaching concrete technology for civil engineering students. It discusses the problems and difficulties encountered in teaching the course from the point view of teachers and learners. Four basic methods that depend on using the senses of the learners are discussed and compared. The performance of the students taught with these methods is analyzed and evaluated. Statistical analysis showing the probable performance of the students in the four methods is provided. The study shows that the best method of teaching is the suggested full practical method (FPM) explained in details in the manuscript. The best method depends on using four of the five senses of the learner. Detailed recommendations and guidelines for the best teaching method are given at the end. Example practical problems for evaluating the real performance of the students are suggested. The application of the FPM is sufficient to end with the outcomes that satisfy ABET requirements without any alterations.

Keywords: teaching concrete technology, FPM method, students' performance

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Introduction

Engineering education is important because the outcome of the education affects directly the development of the whole society. Among engineering, civil engineering is considered the one responsible for the infrastructure where the graduates should be able to provide high performance during their work. Because of the high responsibility of the graduates in such projects, teaching civil engineering becomes an art that require special attention of the lecturers. The graduates of any engineering branch, including civil engineering, should be able to fulfill their tasks perfectly. According to ASCE: "Civil engineers build the world's infrastructure. In doing so, they quietly shape the history of nations around the world. Most people cannot imagine life without the many contributions of civil engineers to the public's health, safety and standard of living. Civil engineering's contributions to daily life, including transportation, clean water and power generation, are magnificent in scope and functionality. Simply stated, civil engineers are creative, people-serving and problem-solving leaders who make our lives easier to live from one day to the next." Because of its importance to the society, civil engineering education should end with predetermined aims and outcomes. According to the ABET¹ Accreditation Policy and Procedure Manual and Atkin et al.,² the 21st century civil engineer must demonstrate the fifteen points a to k in Aktan et al.²

One of the major needs for high quality engineers is the high competition among engineering graduates from various universities. Nowadays, many countries suffer from unemployment. Therefore, engineers have to travel and work abroad. These engineers have to compete among colleagues for available positions. For example, many engineers from all over the world work in mega projects in the Middle East. In some cases, fresh graduates are allowed to supervise small concrete projects. These fresh graduates need to be good supervisors and decision makers from the start. Therefore teaching concrete technology must end with graduates who are able to take decisions in specific construction projects. Many civil engineering educational experts suggested innovative methods for teaching various topics required for civil engineering students. Several researchers introduced different methods for teaching basic courses such as statics, dynamics

and strength (mechanics) of materials. Vikas et al.,³ described a teaching method for statics and dynamics courses by developing a long term scalable system which connects different kinds of resources and has an integrated system wherein any instructor can set up his own class, manage his own set of students and administer testing and evaluation methods. Gramoll⁴ showed the benefits of electronic media in engineering, such as interactive simulations, three dimensional visualization and animations in teaching statics. Steif et al.,^{5,6} described highly interactive classroom methods for teaching Statics. These methods allow students to use special concepts, test their understanding of them, and refine that understanding through spirited discussions with peers. Litzinger et al.,⁷ presented a cognitive study of problem solving in Statics and discovered differences between weak and strong students. Flori et al.,⁸ presented software for teaching dynamics. Rueda⁹ developed a teaching method for mechanics of materials by using lab experiments to enhance students' understanding and performance. Vassigh¹⁰ used digital technology for teaching statics and strength of materials. He concluded that such use can help build a strong understanding of complex structural concepts and principles which can be explained in an easier way.

In addition to the basic courses, other researchers suggested new methods and concepts for specialized civil engineering courses. The following paragraphs summarize some of their research. Rumsey et al.,¹¹ Haque et al.,¹² Al-Ansari et al.,¹³ introduced new methods for teaching reinforced concrete. Rumsey et al.,¹¹ described a method for teaching reinforced concrete for undergraduates through the use of ACI building code, implementation of Microsoft Excel programming exercises and a full-scale design, construction, and testing project. The students' comprehension and retention of reinforced concrete design was greatly enhanced. Haque et al.¹² suggested a new method for teaching reinforced concrete by the use of 3-D drawings and physical models. The method implies 3-D animations and virtual walkthrough on reinforced concrete construction detailing. Al-Ansari et al.,¹³ used MathCad for teaching reinforced concrete. Jimenez et al.,¹⁴ suggested a new method for teaching highway engineering. They compared the traditional method for teaching highway engineering with an innovation method based on the lecture, solving problems at home, students' self-assessment, continuous assessment exams, the

use of virtual tutorials and the use of commercial software– design of roads. Mahendran,¹⁵ & Arciszewski et al.,¹⁶ introduced methods for teaching steel structures. Mahendran¹⁵ showed that improvements to teaching and learning steel structures were made through integration of a number of related structural engineering subjects and by the introduction of animated computer models and laboratory models. Arciszewski et al.,¹⁶ suggested a method for teaching structural design for the 21st century engineers by the use of Internet–based multimedia systems. In this method, in some cases, the students are left to make some studies by themselves and are encouraged according to their performance. Work by Tehrani¹⁷ & McComb et al.,¹⁸ offers a single framework that merges teaching methods for early and advance engineering courses. They showed that experiential learning is a key component in engineering education. They also studied the applicability of situational leadership in teaching engineering courses. Lin et al.,¹⁹ showed that teaching life– cycle thinking (LCT) in construction engineering and management would be beneficial for both the learner and the teacher. Although there are many papers that discuss teaching civil engineering topics, only three are available on the Web for teaching concrete technology and materials. Katz²⁰ described an effective method for teaching concrete technology by improving the efficiency of the laboratory program and developing a special program for a remote laboratory classes. Tito– Izquierdo et al.,²¹ described a method based on teaching concrete technology lab by testing mixes designed and prepared by the students. Application of ACI mix design spreadsheets was used and various properties were measured. Baharom et al.,²² described a problem– based teaching method for concrete technology lab. Although the last three papers introduce new experience in teaching building materials and concrete technology, no single paper was solely dedicated to teaching concrete technology for decision making engineers. They discuss teaching labs rather than the whole course.

Concrete technology course

Concrete technology course is a core course in civil engineering.

The course concentrates on the use of materials (cement, aggregates, admixtures and additives) in concrete production; the various correct methods and procedures for the production of concrete (batching, mixing, discharging, transporting, pouring compacting and finishing); durability problems and requirements of the hardened concrete, such as alkali– silicate reaction, sulphate attack, steel reinforcement corrosion, frost action, shrinkage and temperature cracking and problems, ...etc; mechanical properties of hardened concrete; proportioning concrete mixes using various methods; testing and evaluation of materials; compliance with specifications. Also in the course, the teacher has to explain for his students that they must be aware of their site conditions and should be able to use the information and technology taught in the course in his site work. The teacher must explain that, sometimes, they have to take vital decisions instantly. The course differs from design courses, such as reinforced concrete and steel structures as described herein. At site, the graduate must base his decisions on some information he studied and memorized in the class. The references may not be there. On contrary, a graduate at a design office can easily refer to any reference book. Unlike sites, offices provide the design engineer with whatever required. In addition, the student should be able to investigate and control the materials and procedures by continuous testing and evaluation, while this is not required in design courses. Furthermore, the student should have some strong leadership personality in order to be able to effectively supervise and control the site. Therefore, the course is characterized by two basic parts. The first part is concerned with ability of the student to memorize some principles, procedures and figures. For example, the student must know the tests that should be made in order for a material to comply with some specifications. The second part is based on mathematical formulas and calculations such as sieve analysis of aggregate, concrete mix design, etc. In general, the student should be able to remember some information and to also to analyze and interrupt data. In other words, the engineer should be able to comply with the 15 points demonstrated by ABET¹ & Aktan et al.² These points are shown in Table 1.

Table 1 Non– native Language+ Survey

Question	The textbook non– native language	Native language	Does not matter
Concrete technology			
Which language do you prefer for your main course references?	14	54	32
Which language do you prefer for teaching in the class?	2	90	8
In which language would you do your search on the web to find more and better information?	82	18	Does not apply
Which language do you prefer in the exams (the questions and the answers)?	28	56	16
Statics			
Which language do you prefer for your references?	66	12	22
Which language do you prefer for teaching in the class?	26	74	10
In which language would you do your search on the web to find more and better information?	86	14	Does not apply
Which language do you prefer in the exams (the questions and the answers)?	56	24	20

+The non– native language is English

Expected problems encountered in teaching concrete technology

The following paragraphs summarize the special problems encountered in teaching concrete technology.

One of the important issues is that the instructor should be aware of “what’s going on” in sites. In other words, practical site experience is a must.^{20,21}

The teacher should always be aware of the latest developments in concrete technology and materials and be able to teach them to the students. For example, according to Tito–Izquierdo et al.,²¹ students need to understand modern developments in concrete such as: high performance concrete, very high strength concretes, self– compacting concrete, and green concrete among many newer concepts. All these topics may not be found in a single textbook.

The student should be able to analyze and solve some engineering problems mathematically and apply his knowledge in complying

Course Number	0620-252
Course Name	Engineering Materials
Pre Req.	(Pre-requisites: 0600-204)
Credits	(2-3-3)

Description	This course aims at providing students in-depth knowledge of construction materials and their utilization in Civil Engineering fields. The course covers manufacturing process of cements; types and properties of cements; properties of aggregates and their gradation; preparation of concrete materials; factors affecting workability, tensile, compressive and flexure strengths of concrete; durability of concrete; and mix design of concrete. Students will have experience with manufacturing bituminous binders; properties of bituminous binders and mixtures; design and uses of bituminous mixtures; manufacturing process of steel, various steel composition and structure of steel, heat treatment of steel and alloy steels.
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Figure 1 Description of Building Materials Course in Kuwait University

(<http://www.eng.kuniv.edu/civil/?com=courses&act=view&id=243>)

If we consider both the theoretical and the practical aspects of the course, no single textbook can provide the whole material. Moreover, the textbook may not be suitable to teach the experience required at site. For example, a textbook needs to be accompanied by some local or international standards. Tito–Izquierdo et al.,²¹ included some ACI and implicitly, some ASTM specifications and standards in teaching concrete technology.

The course needs to be accompanied by lab work to allow the student to practice the material taught in the classroom. To solve such problems, Tito–Izquierdo et al.,²¹ described teaching a lab course in a modern way at the University of Houston–Downtown. They achieved the best in solving such problems. Katz 1999 described a special remote lab for teaching concrete technology.

Modern multimedia technology is necessary both in the classroom and in the lab.^{16,20,25} In this respect, Katz²⁰ prepared a digital lab textbook, which was placed on the Internet, for the lab experiments. He also included some photos and videos. Tito–Izquierdo et al.,²¹ used a special computerized ACI mix design sheet in the lab.

A special problem encountered in developing countries is that the student must be fluent in another language in order to refer to good textbooks and references. Because of that, the student may not be able to fully understand the lectures and notes and sometimes he may

lose vital points. This problem is much less encountered in topics that are based on application of formulas and equations, such as statics. There, the student can easily follow–up the material by referring to solved problems. To justify this assumption, the students attending the concrete technology course this semester at the Hashemite University were asked to fill a special questionnaire. The questionnaire and results are shown in Table 1. All students who filled the questionnaire finished statics. The results of the questionnaire support the argument in this paragraph.

One of the major problems that face both the instructor and the student is that some universities included other building materials in the course of concrete technology. This will be too heavy for civil engineering students and lecturers. An example is the compulsory 3–credit hour course (2 lectures+1 lab) given by Kuwait University (Figure 1). This problem may not be observed at some other universities. For example, in some universities, there are two compulsory courses offered for civil engineering students in building materials. The first is a 3–hour credit course (3 lectures per week) and the second is a 1–credit hour lab course. In some Middle Eastern countries, both courses are solely dedicated for concrete technology.

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Aims of the research

This research aims to discuss the possible various methods used in teaching concrete technology and their effect on the outcome of the students. Later the research suggests the best teaching method and technique. By the use of the correct method, the student will be able to fulfil the 15 points demonstrated by ABET¹ & Aktan et al.,² Thus the graduate will be ready to the 21st century and hence be able to supervise small concrete projects and, sometimes, take vital decisions. The research describes several methods that have been developed through teaching concrete technology at several universities for a long period of time. The course syllabus and the credit hours differed from one university to another. Also many were taught before getting the teacher’s own site experience.

Description of the methods of teaching

Method 1: See–Hear–Study (SHS)

In this method, the lecturer is the sender of the information; the educational material is delivered through chalk and black– or white–board, overhead projectors or PowerPoint presentations. The student can see and hear his teacher and hence he uses two of his senses. The student is the receiver of the message. This method is sometimes called “the spoon– feeding”. Although this is the traditional old method for teaching, it is still popular and widely used. In this research, the SHS method involves three different sub methods (SH1, SH2 and SH3). In SHS1 the students are required to follow and study a certain textbook. In SHS2 the students are given the simplified lectures’ material including the PPT presentations and are supposed to depend solely on them before sitting for the exams. In SHS3 students are required to refer to some references. They have to depend on themselves for receiving the lecture notes and prepare themselves for the exams.

Method 2: See– Hear–Discuss–Study (SHDS)

In this method, the lecturer uses the previously described SHS method in addition to discussion sessions. In this method, the student receives the information and is allowed to discuss it in the classroom, or sometimes in separate sessions prepared specially for discussions.

Similarly, the method includes three sub groups (SHDS1, SHDS2 and SHDS3). In SHDS1 the students are supposed to follow and study a certain textbook. In SHDS2, the students are given the simplified lectures’ material (including the PPT presentations) and are supposed to depend solely on them before sitting for the exams. In SHDS3, the students are supposed to refer to number of references, rely on themselves for receiving the lecture notes and prepare themselves for the exams.

Method 3: Prepare–See–Hear–Discuss–Study (PSHDS)

In this method the students are required to prepare the new material in advance by referring to specific chapters from one textbook or more. In the class, the student is a main part of the teaching process, and sometimes he introduces the material he prepared by a PowerPoint presentation or some videos. The lecture becomes “an active live guide” rather than “a machine passing information”. The method involves direct questions and answers in interactive learning. The students have the sufficient time for preparing their discussions. They will guide the teaching process in an active manner. In this method, the student has the complete notes, either from one textbook or from several references.

Method 4: The Full Practical Method (FPM)

In the FPM method the students are taught the whole material in the concrete technology lab and at concrete sites during site visits.

By teaching the material in the lab, the student can use **four** of his senses in the learning process.

The student can **see** by his own eyes the materials and equipment;

Hear the instructor and the testing equipment;

Touch the samples and the testing equipment and

Smell the materials (such as cement and fresh concrete).

Moreover, the student can discuss and practice all the information he learns. In all previous methods the student is using only three of

his senses. Furthermore, the students are required to visit concrete sites. There, they can see by themselves the real life and practice of site engineers. Sometimes, the students are taken to predetermined sites (site visits) in order to attain certain knowledge. For example, the students can visit a cement production factory when teaching the manufacture of cement. Another example, the students can visit a ready– mixed concrete plant when teaching ready– mixed concrete. They are able to discuss various construction aspects with the experts at sites. Also, students can discuss ethical aspects. Some students can take photos of “correct” and “incorrect” procedures and then have extensive discussion in the classroom. In these site visits, the instructor should have full contribution in the arguments and discussions. That’s why practical site experience is a major requirement for anyone teaching concrete technology. The students can easily understand the topics. They will also need less time for study than the time they need in the previous three methods. Also the lecturer spends much less time in passing information and knowledge to the students. The students are expected to enjoy the course and consider it as a game of concrete technology rather than a dull course. Fluency in another non– native language is not “a must” here. The student becomes very active and is always ready to practice “the game” of learning. Similarly, Tito–Izquierdo et al.,²¹ used the lab successfully to teach the students new developments in concrete technology; the students were able to achieve their knowledge to the best. In a chemistry course²⁵ education trial, the students in the experimental group had better understanding of the subject and more positive attitude toward guided inquiry instruction.

Analysis and comparison of the methods

In order to analyze and compare the previously described methods, the students were required to sit for two exams in the same material: Exam 1 and Exam 2. Exam 1 contained problems directly taken from the material (textbook or lecture notes). Exam 2 contained more difficult problems that did not totally depend on the material but require thinking and intelligence for solution. Some of the questions were related to practical and some others were brain– storming.

Method 1: See– Hear– Study (SHS)

In order to test the outcome of the method, 50 to 70 students were taught using this method. In SHS3 group, only Exam 2 was given. The results of the exams for the three groups are shown in Figure 2. It is quite clear that the students obtained the highest marks in SHS2 Exam 1 and then in SHS1 Exam 1. This can be attributed to the availability of the material to be examined. However, the marks were much lower in the case of the difficult Exam 2. This proves that the students tend to memorize the material rather than understand and interpret knowledge. The marks were even close to the students who completely relied on themselves without any material available in their hands (SHS3). Also it is shown from Figure 1 that the highest marks were for the SHS2 Exam 1. This can be attributed to the fact that the students have the least amount of material for study. Another remark, in Exam 2, is that the students who had a textbook got higher marks than those who did not have one. It can be concluded that the SHS method is not adequate for concrete technology students. This finding complies with Orlich et al.,²⁶ teaching strategies. The learning mode tends to be passive and the learners play little part in their learning process. Another important conclusion is that high marks do not actually reflect the overall performance and the real achievement of the students and their mastering of the topic.

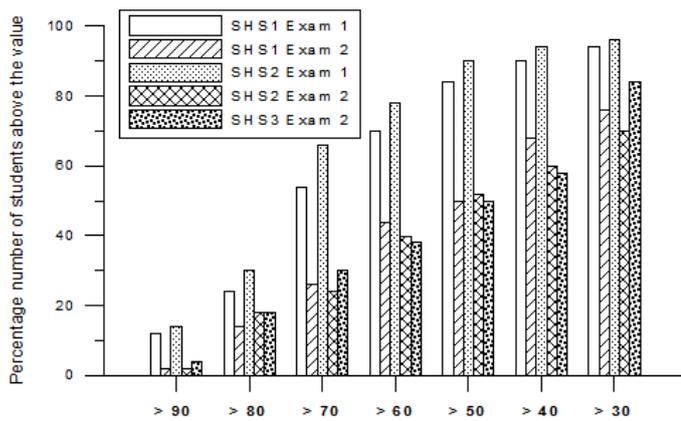


Figure 2 Performance of the students in SHS method.

Method 2: See– Hear– Discuss– Study (SHDS)

In order to test the method, the same procedure that has been followed in the SHS method was applied here. Figure 3 shows the final results. The same general observations and conclusions as in SHS method are noted. However, the marks are higher than those for the SHS method. This is attributed to the fact that the students are allowed to ask and discuss their knowledge in the classroom. Furthermore, the students with no textbooks or handouts SHDS3, obtained higher marks than the other groups, while this is not observed in Method SHS. This leads to the conclusion that the students who use more than one textbook and are allowed to discuss their knowledge in the classroom showed better performance. It is clear that high marks do not necessarily reflect the full understanding of the material discussed in the classroom. In other words, discussion is essential in enhancing performance.

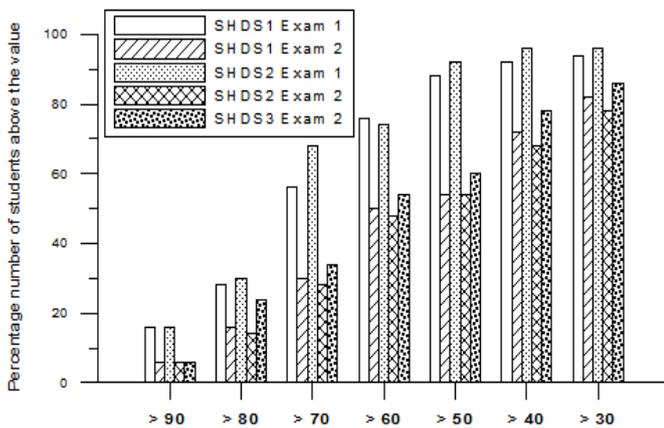


Figure 3 Performance of the students in SHDS method.

Method 3: Prepare– See– Hear– Discuss– Study (PSHDS)

Because of the nature of this method, there were only two evaluation methods for comparison. The first is the one with the simple exam (Exam 1) and the second with the more comprehensive and difficult exam (Exam 2). The results are shown in Figure 4. In this method, the gap between the two exams is much closer than the gap

between the exams in the previous methods (SHS and HSDS). The method required less time in teaching than the HSDS method because the students prepared the topic and can directly discuss critical points in the classroom. The lower difference in marks reflects better understanding and achievement of the material. It is worth notifying that in this method, the lecturer also needs less time to explain and process knowledge to the students which allows him to introduce new advancement in concrete technology.

Method 4: The Full Practical Method (FPM)

In order to test the method, the previously described exams (Exam 1 and Exam 2) were used to evaluate the outcome of the students. Figure 5 shows the results of both exams. It is clear that the gap between the two exams is the least among all methods. The marks are the highest for both exams and nearly no student got a mark below 40. This leads to the conclusion that the outcome of this method is the best. However, this method requires more time than the previous methods because there should be enough time for discussion, experimentation and site visits. Further analysis of the results, based on Exam 2, is shown in Figure 6–8. Figure 6 shows the distribution of the students who attended Exam 2 in all methods. Figure 7 shows the distribution of students who got above 60% in Exam 2 (the 60% was assumed as the minimum required mark to pass the course). Among all, the students who were taught with the FPM showed the best performance. Also, only about 50% of the students were able to pass Exam 2 in methods SHS and SHDS. The distribution of students who got more than 90%, distinction, is shown in Figure 8. It is clear that 20% of the student got distinction while less than 6% only got distinction in SHS and SHDS methods. Statistical analysis of the various methods is shown in Table 2. From the table, it is quite clear that the performance of the students taught with the FPM is distinguished. They had the highest average. Also they had the highest percentage of the students who passed Exam 2 (above 60%) or to got distinction (above 90%). Furthermore, the standard deviation among their marks was the lowest, indicating better proximity in their marks when compared to the other methods.

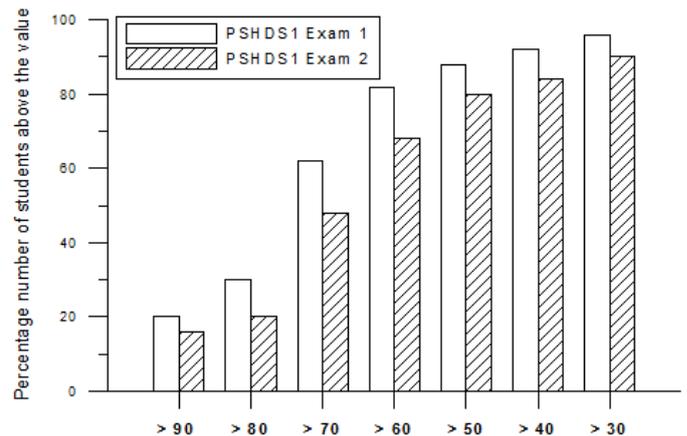


Figure 4 Performance of the students in PSHDS method.

Analysis of the questionnaire

Opinions of students

The students have been asked about the concrete technology course, and these are some of their answers:

- a. "The course is interesting because it is directly related to practice."
- b. "The course is dull and I even slept in some lectures."
- c. "I hated the course. It consumed most of my time during study."
- d. "This is the best course I attended. I did not spend too much time in memorizing".
- e. "This is a very simple course. Small time is spent in studying; one or two nights before the exam are sufficient".
- f. "I liked the course but it consumes too much of my time at home".

All previous answers are correct. The reason behind each answer is the method that has been followed in teaching the material and to the exam the student had to attend. These answers will be discussed in the next section.

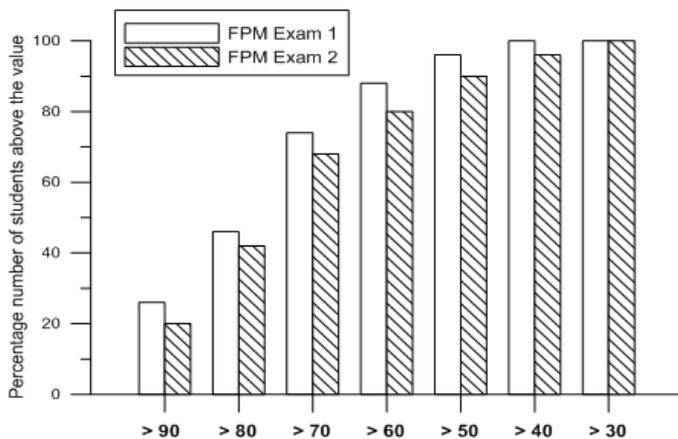


Figure 5 Performance of the students in FPM method.

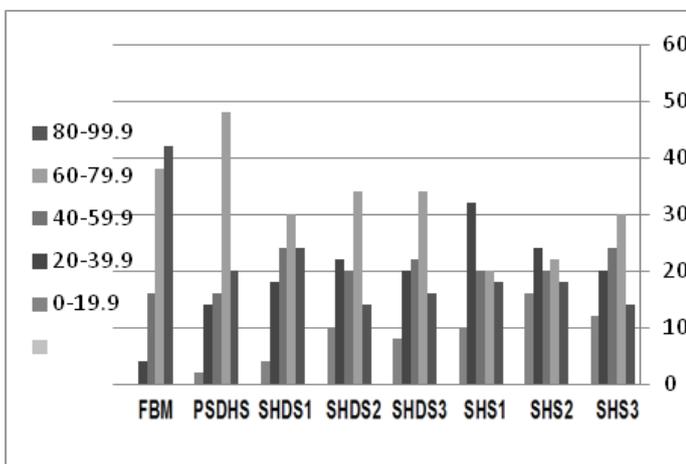


Figure 6 Performance of the students in exam 2 for all methods.

Analysis

A special questionnaire was distributed and filled by the students who were taught by the various methods. The results are shown in Table 3. Among all, the FPM was the most acceptable and enjoyable. 84% of the student enjoyed the course, 80% were ready to have another course related to concrete technology and about two-thirds would be pleased to have a graduation project in concrete technology. Also, in the FPM method, about three-quarters of the students had to

spend less than one hour studying. Hence, the method is comparable for the SHS and SHDS methods where the students are spoon-fed in learning. Furthermore, the students who were taught by the FPM were ready and confident to work at sites. This is probably due to the practical sessions and to the site visits. The percentage of the students who prefer to work at site is about double those who were taught by the SHS and SHDS methods. In addition to the practical discussions at sites, the students who were taught by the FPM method were able to tackle some of the ethical aspects. This was attributed to the discussions they made with site engineers. By their visits and discussions, most of the students (88%) agree that the instructor must have practical experience. This point could not be clearly noted in the SHS and SHDS methods.

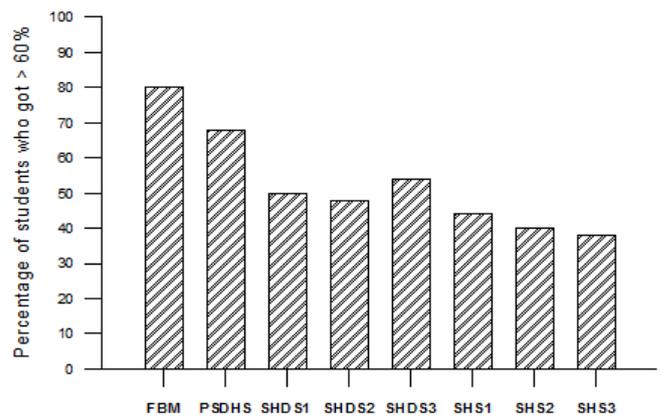


Figure 7 Percentage of students who got above 60% in Exam 2 in the whole methods.

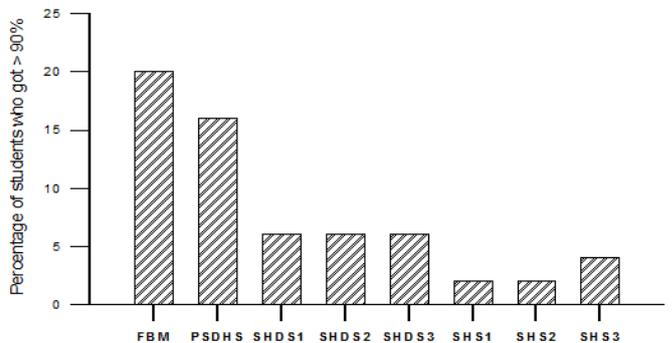


Figure 8 Percentage of students who got above 90% in Exam 2 in the whole methods.

From Table 3, it is shown that 78% of the students are considered to be ready for the 21st century, implying that they have attained the ABET¹ accreditation requirements in the concrete technology course. One of the main problems encountered when applying the FPM method is that the lab should be well-equipped and that all the lab staff must have good experience. This finding is supported by Katz.²⁰ Another problem is that the FPM is time consuming; about three-quarters of the students recommended that the course should be at least 5 credit hours. Rearrangement of the equipment may help in reducing the time for teaching and learning.²⁰ The author suggests that the course be divided into two courses (say 1 and 2). Each is a 3-hr credit course and 1 lab. One of the major aspects that affected the performance of the students is that they are not fluent in the textbook

language. According to all the students, studying by non-native language affected their performance. In this regard, the FPM has the best. This attributed to the method itself where the student uses four of his senses in learning. In developing countries, this problem cannot be easily solved because of the fact that most the high-quality concrete technology references and textbooks may not be available in the

student’s native language. The instructor can reduce this problem by explaining and discussing the topics by the students’ native language. However he can encourage them to use the non-native language in the classroom. For example, extra marks can be given for students who use the textbook language in their discussions and answers (Table 4).

Table 2 Statistical Analysis of the three methods

Method	Designation	Mean value	Standard deviation	Probability for a mark > 90	Probability for a mark > 60
Method 1	SHS1	51.4	24.2	5.5	37
	SHS2	49.6	25.7	5.8	35
	SHS3	51.8	24.6	6	37
Method 2	SHDS1	55	23.7	6.9	43
	SHDS2	53.4	24.2	6.8	39
	SHDS3	58.6	23.1	8	47
Method 3	PSHDS	65.4	21.3	12.5	60
Method 4	FPM	74.6	16.6	17	81

Table 3 Results of the analysis of the questionnaire

Question		SHS*	SHDS*	PSHDS	FPM
Did you enjoy the course?	Yes	44%	56%	72%	84%
	No	46%	40%	16%	10%
	No Answer	10%	6%	12%	6%
How much time did you spend for study (per week)? ¹	< 1 hour	80%	70%	54%	74%
	1 to 2 hours	20%	28%	40%	36%
	> 2 hours	0%	2%	6%	0%
Would like to attend another course based on concrete technology? ²	Yes	60%	58%	52%	80%
	No	40%	38%	38%	16%
	No Answer	0%	4%	10%	4%
Would you like to have your graduation project in concrete technology?	Yes	28%	34%	44%	62%
	No	50%	40%	42%	16%
	Uncertain	22%	26%	16%	22%
Would you like to work as site engineer after graduation?	Yes	30%	38%	54%	64%
	No	52%	32%	26%	20%
	Uncertain	18%	30%	20%	16%
Do you think that you have satisfied the 21st century requirements (15 points)	Mostly	20%	34%	54%	78%
	Partly	72%	70%	34%	16%
	No Answer	8%	6%	12%	6%
Do you agree that the instructor must have sufficient practical experience?	Yes	28%	38%	64%	88%
	No	36%	32%	22%	4%
	Don't know	36%	30%	14%	8%
How many credit hours do you think are the minimum to fulfil the whole course?	3hr	68%	34%	48%	12%
	3hr + (1 lab)	32%	44%	48%	24%
	3hr + (2 lab)	0%	22%	4%	76%

Table Continued

Question		SHS*	SHDS*	PSHDS	FPM
Is the available lab (equipment and staff) sufficient?	Yes	76%	62%	40%	18%
	No	10%	22%	46%	80%
	Don't know	14%	16%	14%	2%
Do you think that the study in the non- native language affected your performance?	Yes	70%	64%	58%	52%
	No	28%	28%	34%	40%
	No answer	2%	8%	8%	8%

*SHS3 is excluded

²The available are two elective courses: "Advanced concrete technology" or "Deterioration, repair and rehabilitation of concrete structures"

The sample number is 50 to 65 students

All values are approximated to the nearest even figure

Table 4 Referring to the questions A to F that appear in section, the answers are summarized as follows

Answer	Method taught
A	FPM method
B	SHS method with PowerPoint slides
C	SHS3 method but the student was not fluent in textbook language
D	FPM method
E	SHS2 method
F	PSHDS method but the student had problems in the textbook language

Learning outcomes

Applying the FPM method, the course learning outcomes support the achievement of ABET outcomes (a to k) and the additional requirements suggested by Aktan.² Table 5 summarizes these outcomes. Altering the ABET¹ requirements to suite some teaching conditions can be done. This can be seen in a Concrete Industry Management course.²⁷

Discussions and recommendations for teaching using FPM

Based on the analysis of the results of the four methods, the analysis of the questionnaire and guided by previous educational researchers, other professional education experts and teaching strategies, the following paragraphs can be summarized. The application of the FPM method can be better if the material is prepared in advance. In addition to the usefulness of preparation in providing preliminary knowledge, it is also very useful for students who are not fluent in the textbook language. They have enough time to read, translate, prepare and understand the material. Heiner et al. reported that pre-reading assignments are very helpful for students learning scientific topics. In order to be active in site visits and practical sessions, the instructor should have sufficient site experience in supervising concrete projects.^{20,21} This experience enhances his discussion with his students in the sites. He can easily differentiate between right and wrong. Furthermore, the instructor should allow sufficient time for discussion of the theoretical or practical sessions including site visits. Discussion of ethical aspects is also important. Point f in ABET¹ requires the engineer to have "an understanding of professional and ethical responsibility". Flynn et al. showed that within the group discussions,

students can learn from each other, thus facilitating and encouraging more independent learning and also providing opportunities for deeper learning. Moreover, ethical learning should be considered and can be achieved.²⁷ The practical sessions should always be taught simultaneously with the theoretical part. It is not adequate to teach the theoretical part first and then the practical one. For example, in many departments, it is allowed to take the 3- credit theoretical part without the practical one. In this case, the student can take the 1- hour practical course sometimes after several semesters. Remembering and re- understanding may not be easy. Therefore, it is recommended that the student takes the two courses in one single course, or at least, it should be compulsory that the practical and the theoretical courses be taken together in the same semester. Katz,²⁰ Tito-Izquierdo et al.,²¹ & Baharom et al.,²² researches support such conclusion by suggesting special concrete technology courses to be taught in labs.

Analysis of the results in Table 3 shows that for the fulfilment of the course material, a 3- credit hour course can only be taught using the SHS method. A 4-credit hour course (3 theoretical and 1 practical) is partly suitable but will not be sufficient to fulfil the FPM method. It is only useful for the PSHDS method which lacks full practical interpretation of the students. For the best outcomes, 76% of the students suggested a course of at least 5- credit hours. Based on that, the author suggests that the course can be distributed into three main parts. The first part is 3 hours for classroom lectures (1 hour each and mainly taught in the lab). The instructor provides the theoretical material using the lab and the multimedia to his best. The second part is a 1 credit hour for practical sessions (usually 3 contact hours). The students work individually or in groups to apply the knowledge. Discussion among the groups is important at the end of the class. The third part is 1 or 2 credit hours (3 or 4 contact hours) dedicated for site visits and special discussions of site work and experience. This part of the course should be at the end of the day (for example 2 to 5 in universities that work 8 to 5 daily. Students should be encouraged to take photos of their work and site visits. An example is shown in Figure 9. In Figure 9, the students can discuss cracking of concrete and how to avoid it. The department may also provide the students with certain equipment for their site work and study. For example, a Schmidt hammer and USPV testers can be used at sites when learning non- destructive testing. The instructor should always keep in mind the 15 points, which include those of ABET, when preparing the exam. By this way, he can get better outcomes of the course.^{2,23} Hence, the exams should test the ability of the student to use the data and knowledge in fulfilling the work. Practical judgment is essential in this respect. Simple multiple choice exams may not be sufficient because such questions, indirectly, may guide the student to the correct choice.

Table 5 ABET Outcomes

	ABET's & Aktan's student outcome	Course learning outcome
a	an ability to apply knowledge of mathematics, science and engineering.	Analyze experimental data, compare to specifications and comply the materials with standards. Design concrete mixes according to ACI 211 and the British DoE mix design methods.
b	an ability to design and conduct experiments, as well as analyze and interpret data.	Study of cement, aggregate, fresh concrete, hardened concrete in the lab. Analyze and interrupt data and comply with specifications.
c	an ability to design a system, component or process to meet desired needs	Use the required fresh and hardened concrete properties to design concrete mixes and test them practically. Adjust the mixes.
d	an ability to function on multi- disciplinary teams	Students work in lab groups collecting data and share technical information. This will prepare them for work in more professional and larger teams.
e	an ability to identify, formulate and solve engineering problems	Identify, test, and report on the tested materials and the best mix design that can be used for various applications. Compare results. Discuss site visits and solve the problems observed.
f	an understanding of professional and ethical responsibility	Discuss site visits, observations and incorrect practices. Meet with professional engineers.
g	an ability to communicate effectively	Students work in lab groups collecting data and share technical information and prepare the best possible report.
h	the broad education necessary to understand the impact of engineering solutions in a global and societal context	Students compare their study with actual life during site visits. They can discuss and suggest solutions in actual construction projects.
i	a recognition of the need for, and an ability to engage in, life- long learning	Students refer to several references, discuss various problems and apply solutions.
j	a knowledge of contemporary issues	Apply recent concrete technology issues in discussions and labs.
k	an ability to understand the techniques, skills, and modern engineering tools necessary for engineering practice	Students test the materials and mixes following international standards and using the new techniques such as nondestructive testing of concrete.
l	an ability to apply knowledge in a specialized area related to civil engineering	Apply their knowledge of concrete technology in the lab, site visits and discussions.
m	an understanding of the elements of project management, construction, and asset management	Contact project engineers and managers during site visits and discuss the issues in the classrooms.
n	an understanding of business and public policy and administration fundamentals	Contact project engineers and managers during site visits and discuss the issues in the classrooms
o	an understanding of the role of the leader and leadership principles and attitudes	Work in groups with a group leader in the lab sessions. Contact project engineers and managers during site visits and discuss the issues in the classrooms.

Development of the lab is important. In addition to the apparatus and machines the lab should also contains by the necessary furniture to allow the students work easily and comfortably as individuals or as groups. The furniture should include sufficient number of benches, sufficient work space, teaching area with blackboard or whiteboard, a data show with full multimedia equipment and a simple bookshelf containing the necessary references. For example, the lab can be provided by parts of the local or international standards and specifications, the copies of some reference books, multimedia films about concrete production and testingetc. Also the lab staff (technicians and workers) should have good experience and should always be available to provide the necessary assistant. Katz²⁰ developed a special ideal lab for teaching concrete technology. The lab suggested by Katz²⁰ fulfils the previous requirements and hence can be used for the PFM method. FPM method, which requires full

contact of the students with each other during lab work, classroom discussions and site visits, helps to develop a better personality, which is a major requirement for site engineers. Lappalainen²⁸ states that "emphasis should be placed on leadership skills development and overall enhancement of intrapersonal skills. Moreover, she stressed that resources should be directed to addressing socio- emotional skills, ethics, values, and attitudes, to allow future employees to more effectively benefit from the technical and substantive expertise at the workplace". Furthermore, the FPM method can provide professional experience to the learners. Warnock et al.,³⁹ stressed that teaching professional skills for engineering graduates is effective at helping students develop their skills in self-directed learning and problem solving. Litzinger et al.,³⁰ stressed that engineering education should encompass a set of learning experiences that allow students to construct deep conceptual knowledge, to develop the ability to apply

key technical and professional skills fluently, and to engage in a number of authentic engineering projects.³¹



Figure 9 Cracking of a slab.

Summary and conclusion

Based on the results of the study and the previous experience of other researchers, several conclusions can be summarized. Students cannot fully understand concrete technology without practical applications, comprehensive discussions site visits. Hence, the FPM will be the best in this regard. Figures 6 to 8 support this conclusion. The simple exams, especially those of simple multiple choice problems, such as Exam 1, do not reflect the actual outcomes and the mastering of concrete technology. Special exams that contain brain– storming questions, practical aspects, interpreting of data and knowledge and mathematical ability (such as Exam 2) are much more useful to test the real outcomes of the teaching process. When choosing the FPM method, major problems arise and should be cared for. The first is that the FPM requires higher budget than any other methods of teaching. Extra costs for the human resources and equipment are necessary. The second is that the application of the method requires a large– space concrete lab which may not be available in existing buildings. Extra space may be required and new construction may be necessary. The third is that modification of the study plan may be required to fulfil the 5 credit– hour course needed for the fulfilment of the method. The fourth is that the number of students per classroom should be limited to 20 to 30 students at most, depending on the capacity of the lab and the available area and resources. This may require new specialized staff members to be assigned. The fifth is that special arrangements may be required prior to site trips. The department has to contact the industry and arrange for the visits. Extra time, money and transport are needed. The sixth is that well– trained technicians and workers are required to supervise the students during work. The modifications required will end produce a better environment for learning and teaching. The remote lab suggested by Katz¹⁹ may help in satisfying some of these requirements.

The application of the FPM is the best to end with outcomes that satisfy ABET requirements. In other words, no special alterations of the teaching process is required for departments applying for ABET accreditation. In some developing countries, a special language course directed for civil engineering students is essential to solve the language problems if the textbook is not in native language. Analysis of the questionnaire in Table 1 supports this conclusion. In order to get the best outcomes of the course, less number of students is allowed

to enrol. Also, additional time is required for the lab work and the site visits. The knowledge and preliminary experience that the student gains when taught by the FPM method encourages him to work in concrete sites (Table 2). Therefore, the method is quite useful for engineers who work at site. They will be ready to take some vital decisions related to practical concrete technology problems. The old common methods of teaching, such as SHS and SHDS methods are not sufficient for teaching concrete technology and may be misleading. The final grades do not necessarily reflect the full understanding of the topic. The results shown in the figures support this conclusion. If the application of the FPM cannot be achieved, the instructor is encouraged to use the PSHDS method or a partial combination of both PSHDS and the FPM methods. This may be quite helpful when the budget does not allow the development of the lab. The outcomes of the course are affected by the number of site visits, classroom lectures and practical lab sessions. Therefore, it is important to investigate the percentage needed for lectures, labs, discussions and site visits when teaching concrete technology. This is the basis of a study which the author is conducting now.

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Conflict of interest

The author declares there is no conflict of interest.

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