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Top-Down Learning Pedagogy for Real Time Embedded System Design

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Abstract : This paper presents an innovative pedagogical approach for average learners to implement projects by effectively fitting their knowledge in solving real-world problems. In particular, it concentrates on embedded systems and embedded signal processing as the current world is experiencing through digital era. Even though both courses are taught, only less numbers of students are opting for embedded projects due to fear of coding and lack of fitting their knowledge appropriately. The focus of this study is to make students to come out of fear by following top-down teaching learning methodology for the design and implementation of Electro Cardio Gram (ECG) data acquisition system. Accordingly, initial interest has been generated by taking the students to the hospital where doctors acquire ECG routinely for their patients and do Fast Fourier Transform (FFT) to observe the spectrum for diagnosis purpose. Every real time system uses high level language for implementation. However, non-computer science students always found it difficult. In order to make the students to come out of fear, simple scripting language MATLAB was tried first. MATLAB coding demo was given to observe the waveforms and an exercise was made to correlate with actual workplace. After interest creation phase, the relationship has been established between the practical they did and the workplace instrument. In the final stage, their learning process was activated by applying inquiry-based (Masoodhu Banu et al. (2020)) learning. Once the quest for real time implementation was created, it was observed that the student's curiosity was increased enormously and was instituted to be effective coders in solving real time applications with more confidence

Keywords: Top-Down learning, Bottom-up learning, ECG, Active learning, embedded system

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I. Introduction

Kinder garden students in a multi-language environment or any toddlers primarily learn any language without knowing the grammar, words, etc. This is due to the curiosity they have in mingling with others. Current generation students are found addicted to gadget looks for something catchy in whatever they do. In studies too, motivation is needed to trigger their learning. The word catchy does not mean just motivation here and it is really an attractive reason to be generated for the learners sometimes it happens by engaging them with an arrangement called active learning methodology (ALM). Numerous

ALM has been in the literature for more than two decades and while it suits for the learners with self-interest it failed with underprepared learners. Despite the decades dedicated to the study of engineering education with an emphasis on Informatics and Computing, there are still shortcomings in the main variables that intervene in the effectiveness of its teaching. Previous theoretical studies (reviews and systematic mappings) have only focused on certain variables of the education of Informatics and Computing such as game-based learning (T. Sujithra & N.M. Masoodhu Banu (2021)), project-based learning (D. R. Ambika(2015)), and problem-based learning (Paresh Tanna(2022)). In addition, in the last two decades, there has been significant change in technology that the student has to learn more basics in their domain before they apply those skills in practicing. In a four-year curriculum it is very difficult to do everything including basic science courses. Hence it is the need of the hour to make relevant teaching technology in an age of accelerating change in technical education.

In educational research, top-down theory exists in literature, both in the field of teaching methodology and curriculum design. Sun R(2012) has defined top-down learning as knowing the explicit knowledge first, and then, learning hidden knowledge on that footing. A baby learning its mother tongue can be given an example here. Bottom-up learning developed by Gibson (1966), is gaining implicit knowledge first, and then, learning explicit knowledge on that foundation. As an example, learning the grammar first and learning to construct sentences based on that comes under bottom-up learning. Similar to top-down approach, the designers used reverse engineering to analyze the product in industry, extract the design to recreate the product or simply to understand how the product works. Specifically, they used when there is no documentation available. Regularly it was used in the field of mechanical engineering (Fanisam et al 2017 & Ali et al 2013). In software engineering, reverse engineering was done for software maintenance (Xiaomin et al, 2004). However the author Hall in (Hall 1992) says that it is necessary to understand the intended purpose to understand the code when we do reverse engineering. Even for an experienced design engineer, it is necessary to have the particular application/domain knowledge to do an effective reverse engineering design or analysis. This is where top-down/bottom-up theory comes into the picture.

Top-down and bottom-up processing are two approaches discussed exclusively in reading research and literature (Abraham, 1985 & Field 2004). According to Paran, (1996) top-down processing also known as concept-driven model, emphasizes on contextual factors and proceeds from whole to part. In other words, top-down processing happens when the reader activates his/her world knowledge to facilitate comprehending the text. On the other hand, in bottom-up reading model, the written or printed text is the centre of attention and reading proceeds from the part to the whole. Thompson & Licklider (2011) applied top-down design for teaching language and observed that student's in-depth knowledge and their ability to search for and find information is enhanced. While it was applied mainly in teaching languages earlier, recent researches started applying in curriculum design and teaching courses in engineering too. It has been observed by the authors Nitza Davidovitch & Zvi Shiller (2016) that courses constructed using a top-down design makes the teachers clarify to students in advance what they are expected to learn, do and understand by the end of the lecture or course. Course outcomes are the priority rather than the course contents in top-down course design as it automatically leads the teachers to right content in addition to knowing the outcome. Siegfried (2012) conducted research to examine top-down and bottom-up approach for teaching/learning an existing syllabus. The study revealed that considering the syllabus simply as a reference model with conceptual limits and ambiguities, a simple projection of top-down approach moved the candidate's values away from their individual skill scope and expectancies. On the other hand, the author found that a process to guide a vocational in defining his/her competency was resulted from a bottom-up approach and in addition confidence was significantly improved during the bottom-up approach and have been maintained over time.

In another study by Maria Knutson Wedel et al. (2008) have mixed results in the process development to integrate environmental sustainability into an engineering program. The faculty who was experienced in formulating the learning objectives accepted the top-down approach combined with support for the benefit of the students. Top-down learning has also been adopted by the authors (Andy et al. 2012) in an attempt to give awareness about STEM education among school children. They have reported that the sense of accomplishments inspired the students to continue their education in STEM field.

Covill et al. (2007) has presented their study on top-down practical approach applied to course engineering mechanics. The research involved students with poor mathematics background, but the course demanded good mathematics knowledge. The project based on top-down approach followed by the authors received positive feedback from students as they were able to test whatever they learnt in theory. According to Margaret (1995) if the prototype can be done very quickly by the students the learner feels the sense of ownership of their product and sense of belongingness in the learning community. The authors Eko Setiawan et al (2017) explained the control system course with high mathematics using top-down learning. They followed the steps like solving the problem to show the results, then explaining the mathematical modules and finally completed with explanation of each equation within each mathematical module. Muhammad K.Akbar (2018) investigated a new approach called TOP-DOWN-TOP (TDT). In each TDT class, students are first presented with a familiar paradigmatic system of systems {TOP}. They were asked to focus down on a subsystem relevant to the systems they studied by learning the principles underpinning its operation {DOWN}. They also made to return to the overall system to discover how the subsystem just studied interconnected with other subsystems to impact the function of the device

On the other hand (Tom Dalling, 2020) in the bottom-up approach the general programming skills and engineering concepts are learnt first and then proceed towards prototype. Top-down or bottom-up, the real software projects need lot more skills than mere concepts and theory alone and hence it is not sufficient for the learner to prepare and work on. This paper addresses this issue by formulating a process for imparting knowledge using Top-down methodology.

2. Problem Definition

The primary learning goals of the course are to teach students about implementation of engineering principles what they studied in theory. In the digital era, almost all the products are implemented using digital technology at least with minimal coding. In the last two decades, the programming languages did not get much attraction. But today, not only computer science engineering students, all-inclusive from automobile engineering to electrical engineering students need to learn coding as everything becomes automated systems. However, students do not realize the value of coding and it is partially because of the traditional teaching style. Unfortunately, the curriculum also concentrates on Simulation Software rather than high level languages. However, in the Google era, plethora of open-source codes can be found in almost everything. The learner needs to know how to stitch the various modules which is done by the proposed top-down learning approach. The stitching part conforms to implementation phase of CDIO. Explanation of the theory is easier, but only practicing gives the confidence to operate in the workplace to move on. It motivates to derive our research question as follows.

"Does top-down learning methodology improve student's learning ability?"

3. Research Methodology

The students from III-year Biomedical engineering was considered for the study. Nearly half of the class was with below average students due to their weak background knowledge in Mathematics. They do not have any mastery of goals except to acquire minimum required grades for getting the degree. The overall objectives of our study are listed as below.

1. To experiment the effectiveness of top-down learning methodology

2. To propose a process which enables an effective top-down teaching methodology

3. To identify the barriers (underprepared students)

In order to examine the goodness of top-down, topic on ECG filtering using Texas floating point processor TMS320C6713 was chosen. We have chosen the following topics combining two courses i.e., Digital Signal processing and Biomedical Instrumentation. The selected outcome of the present study chosen from the courses is

1. Write DSP coding for basic DSP algorithms

2. Design amplifiers used for measuring bio signals

A. Process Involved

The foremost important step in any teaching

methodology is interest creation phase as without interest students refuse to have attention. This phase is named as catch-up phase. Top-down learning designed for the study happens entirely in scaffolding path next to interest creation phase. Parallel distributed process (McClelleand et al, 1987.) discussed that learning takes place within the brain via the activation of nodes and pathways. With increased activation, the nodes and pathways become stronger and easier to recall (Jun Liu & Cynthia Berger). In this dissertation, scaffolding step was used as an activation technique. It activated student's memory to recall old concepts studied and connect to present context. According to King and VanHecke, (2006), "Skill theory suggests that students use cognitive frameworks to solve problems and those concurrent problems inspire new learning. Hence, in the next step, in order to improve developmental skills and help the student achieve the required ability, the students were consistently challenged and supported by the teacher. This phase is referred as demanding phase.

The proposed approach mainly concentrates on three phases, namely catch-up phase, scaffolding phase and demanding phase. The step to be implemented in each phase is given below.

1) Catch Up Phase

- Show the real world example at their work place for the top-down model test case(ECG)
- Present the same as a lab model to hone students' interest in learning either using MATLAB.
- Design course interactions with flexibility for the variable learner profile

2) Scaffolding Phase

- Design compilation issues that will make the learners to reflect by including intentional mistakes in the compilation process
- Design questions that will make the learner to look out for connections for conceptual understanding
- Design questions to connect the programing concept with course concepts

3) Demanding Phase

· Make the students to get real-world answers to "why" questions and bring learners through the discovery process together.

B. Process Implementation

Step 1 of catch-up phase is used to motivate the students to learn, what they need to learn as a part of their curriculum. A sense of accomplishment was seen among the students when the same is executed by themselves as a model in their laboratory. Accomplishment is not enough as the model done is in a procedural way. The inner details start from compilation of big codes to integrating software and hardware. In their freshman engineering course either they do it away with error free readily available code or with the minimum code size. It is natural for anyone facing the issues in compiling a heavy code. Hence, scaffolding with compilation process is also crucial one. The scaffolding phase was done in two phases as explained below.

1) Catch Up Phase

The main objective of the catch-up phase is to make all the students to be comfortable in doing a project of their own irrespective of their cognitive level. It is achieved through design of course interaction questions with flexibility. Hence, even an under prepared student can answer and get at least 25% of confidence in doing the project with their own interest.

2) Activation Phase

It is the process of enabling the students to recollect their previously acquired knowledge, link with the new concepts that will be retained forever by designing suitable activation questions.

It concentrates more on technical aspect i.e. input, output of filtering module and linking it with their previous learning. Hence, the different kinds of questions were carefully designed to stimulate their critical thinking and linking their programming and course knowledge which they have obtained in previous semesters. Sample questions designed to stimulate the critical thinking are given as below.

1. Could you identify where the input has to be given? Is that analog or digital?
2. Can you give the test subject input directly?

3. How was the waveform looked like?

4. Have you seen those waveforms in books? If so relate it and give the similarity and differences.

With the question number two and with some intuition, they understood it is not possible to test the circuit directly with the test subject. Hence, students were guided to test with sinusoidal signals in the frequency range of ECG. By doing this student understood that before field test unit testing is necessary and also, they appreciated the value of the laboratory experiments they did with signal generator they do in the lab. The question number 4 was mainly to motivate the students to look out for the reason why real time waveform is continuous? The students could spot out a difference that bookish waveforms are one single capture and real-time capturing is continuous and periodic. Carefully designed questions lead to the integration of the compartmentalized knowledge and make it usable.

After stimulation, the students were asked to answer for the pre designed questions as listed below to link their acquired programming knowledge in solving real world problems.

1. Could you identify how the actual analog signal captured is converted to digital?

2. To convert to digital what is the important parameter needs to be considered.

3. Find out the code section which reads the analog signal and converts to digital?

4. Why do you need sampling? Where this sampling is achieved? Is it hardware or software?

5. If it is a software or hardware? Justify.

6. How the acquired digital output from the microcontroller is converted to equivalent analog value?

7. What concept is used to find the analog equivalent?

From the conceptual questions they understood, what is sampling and where it needs to be applied. Also, they understood the relevance of the formulas they studied in analog to digital conversion and whether it is to be done in coding. Even though, they have studied these concepts in 8051 microcontrollers and digital signal processing laboratory courses, it was similar like understanding addition and subtraction in primary school and not their application in purchasing goods at the shop. Hence, it is mandatory that any engineering concepts need related application to make the students to have a meaningful understanding.

Demanding phase is followed by activation phase. In this phase, questions were designed in application point of view. It enables students to map their technical knowledge in solving the real-world problems.

Sample questions are listed below.

1. What type of a filter is used? Could you understand why those cut off frequencies?

2. Do you know how that cut off frequencies are decided for ECG system?

3. Could you use the MATLAB version for real time product version?

4. In addition to floating point processors you used, what are the other types of processors available. If both are given to you which one you choose?

The answers to the question 1 & 2 make the students to discover the relationship between sampling theorem, A/D converter sampling setting and FFT. Hence, students will able to design any data acquisition system. The answer to question number 3 in terms of execution time and memory makes the students to understand scripting languages like MATLAB is not suitable for real time products. Question number 4, not only makes him to aware of the other type of processor, also it makes him think why such variation and what circumstances he can go for floating or fixed processor. Questions that lead to healthy discussions will help the students to retain their knowledge in addition to conceptual understanding. Ultimately, faculty needs both insight and competency for the design and delivery of each question. Students were ready for reverse engineering the code along with the engineering concepts after the process guidance was over. The expected outcome is that, at one point of time, students connect their academic place learning to workspace learning to some extent and this was in harmony with the operate phase of CDIO. Finally, the assessment was done by changing the design parameters to

rewrite the code appropriately. It shows that including few underprepared students performed well. In order to study, top-down and bottom-up approaches and its effects on students, the students were asked to fill pre-survey questions to measure their level of understanding in embedded software/hardware related courses and their confidence in doing their project. Later, in the post survey the same questions are asked to analyze the effect of top-down approach followed in this research. The results of pre-survey report are taken as a base-line for comparing the effects of the proposed top-down approach. It is discussed in detail in the following section.

4. Research Design

The sample size taken for the study is about 40 students from Biomedical Engineering. The actual course was conducted for 2 hours laboratory class and one hour theory class weekly. However, the duration taken for study is of the total 12 hours of teaching hours and one day field visit to a nearby hospital. This is done to kindle the curiosity among the students, though the same ECG instrument was available at the Institute. But students were given a week's time for self-study and to do critical analysis. In addition to the usual assessment like conducting an exam, a set of feedback question both yes or no and descriptive questions were designed to analyze the methodology developed. For assessing the proposed learning approach, we conducted pre and post surveys. We have designed yes/no and descriptive type questions for better analysis. Binary assessment questions given in table [1] are common for both bottom up and top-

Table 1: common binary assessment questions designed for both pre and post survey

Question ID	Common feedback questions regarding the effectiveness of Bottom-up and top-down approaches in Learning
1	Do you fear for missed out a section in coding?
2	Do you feel confident in understanding MATLAB/C programming written by someone?
3	Could you improve your critical thinking skill?
4	Does it stimulate your curiosity to learn?
5	Have you got confidence in debugging?
6	Do you have confidence to code a new functionality?
7	Do you have confidence to use a new tool?
8	Has it improved your analytical skills/Reasoning Skill?

Table 2 : Descriptive questions designed for both pre and post survey

Question ID	Pre-survey Questions
1	Do you like the model of bottom-up learning? If so, why?
2	What was the difficulty you faced in bottom -up learning when you learnt C coding in your freshman engineering?
Question ID	Post-survey Questions
1	Do you like the model of top-down learning? If so, why?
2	Can you write your own code for some big projects? If so, how?
3	List the skills that you have developed?
4	How confident you are to code a new functionality? Substantiate your answer
5	How confident you are to use a new tool?

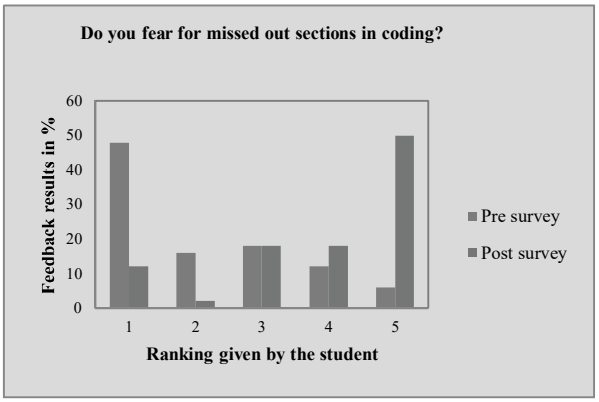
down approaches to measure comparative effectiveness. However, for qualitative assessment, specific descriptive questions also designed as shown in table [2]. As the number of students involved was less, a simple statistical analysis was sufficient to arrive at the results.

5. Results And Discussion

The method implemented was analyzed for various performance factors from confidence, knowledge acquired to higher order skills. Though students have learned the course and scored average to higher grades in bottom-up process, applying the concept to real time scenario was very difficult for them. For the faculty it was actually a redo exercise in guiding the students. Around the world, students always used to be reluctant to ask questions in front of others for the fear of being bullied by fellow students (Hwang et al (2002 & 2009) & Good (1987), At the initial stage, the students involved in our study are no exception and they did not even answer for the scaffolding questions raised by the faculty. Hence, initially the classes went in silence like lecturing and this was due to the low confidence in the connected courses they learnt already. After the few classes, the trial-and-error process of learning in scaffolding phase gave confidence to speak out and their confidence level could be assessed on the go. The research is conducted in two stages namely pre-experiment and post experiment for better validation. For the assessment, specific questions were carefully designed and evaluated, Common binary type questions were designed for both pre and post survey for better comparison. We used the scales for better analysis. Scale ranges from 1 to 5. It is defined as 1. A lot, 2. Quite a bit, 3. Somewhat, 4. Not much and 5. Not at all. In addition to binary type questions, 2 pre and 5 post survey descriptive questions were designed as given in table[2] These questions were designed to test the concept they learnt with top-down methodology. The descriptive questions needed a deeper knowledge about the course taught.

In the assessment, students were asked to write code with some sections already in to mimic the coding available on the internet but with some errors. There was a great improvement in writing the missed-out sections after post top-down learning. However, it is within 50% as in Figure 1a. Figure [1.b] shows still proficiency needs to be improved for understanding others coding. This will come with repeated practice. The ultimate aim of any pedagogy is to create interest in learning at the prime level. This has been achieved and is shown in Figure 1a. i.e., interest level raised from 60 to 80%. From the survey results, from figure [2.b] and [3.b] it is observed that the vast improvement in critical thinking and analytical reasoning is needed yet. Figure [3.a] shows that debugging skill has been increased a lot due to top-down learning. This is the major accomplishment as in industries most of the time they reuse the code and hence debugging skill is mandatory.

It can be seen that with respect to tool usage (Figure 4a) all students are little comfort even in bottom-up learning. This shows their interest with no proper learning methodology given by their teachers. Figure 4b shows their confidence in coding a new function, which is different from missed out section. And is little higher compared to missed out section. It is because integration with someone code is not needed. Though the scores as shown in most of the figure are less, the comparative score reflects that the students have acquired some knowledge though it was not sure what exactly they acquired. But this score combined



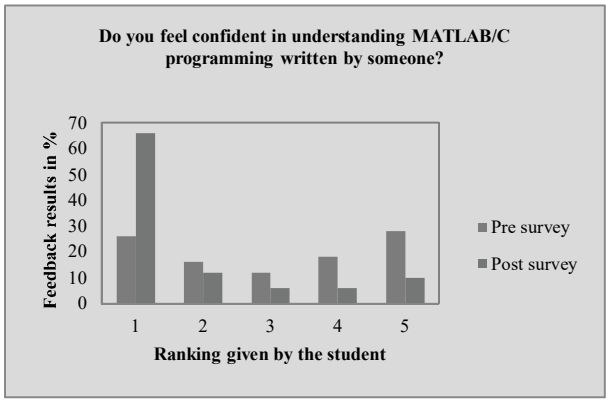


Fig. 1 a & b : Response chart for survey question 1&2

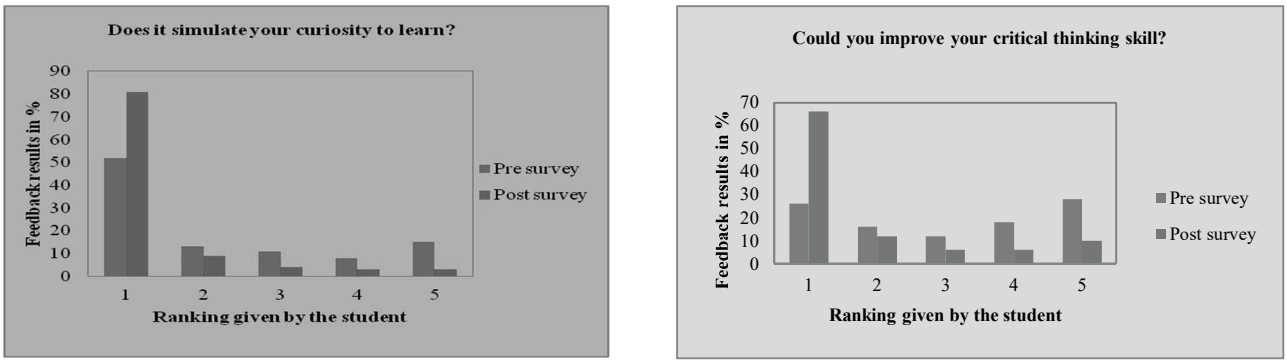


Fig. 2 a & bResponse chart for survey question & 4

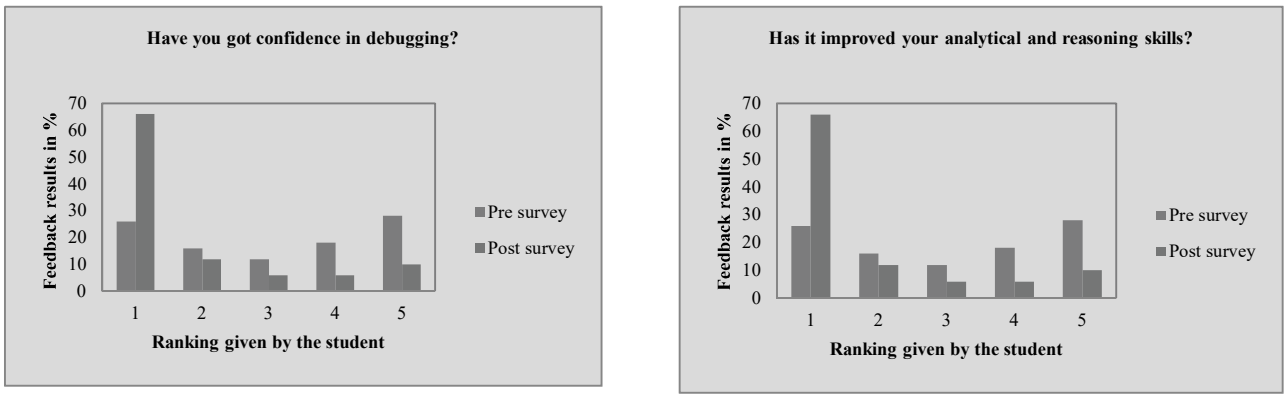


Fig. 3 a & b Response chart for survey question 5 & 6

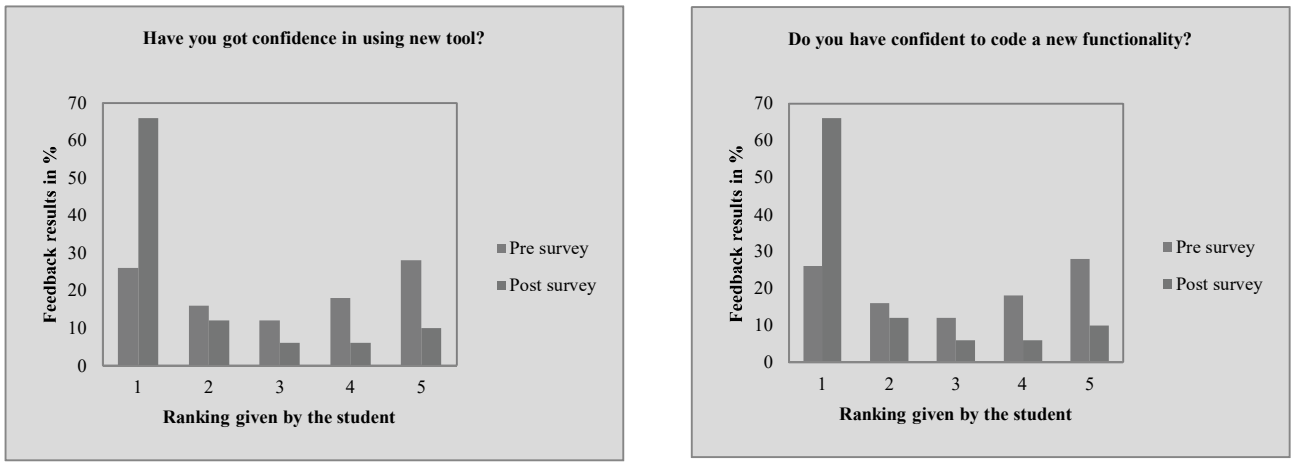


Fig. 4 a & b Response chart for survey question 7 & 8

with their confidence to speak about the subject proved that students definitely acquired knowledge in the part delivered by the faculty. The descriptive answers given by the students also were not very vague. The analysis of pre and post test scores also showed that the medium-level cognitive capacities (level 3 of blooms taxonomy) of average students were improved through top-down learning when compared with a bottom-up approach. Also, top scorers could demonstrate higher capacities in the blooms level i.e., they could evaluate different designs for the same EEG system based on TEXAS processor.

6. Conclusion

In summary, students liked the concept of top-down learning and the catch-up phase seems to be a striking phase as it attracted all the students irrespective of their cognitive level. Secondly, it increased the student engagement though it is not like a gaming pedagogy and all the students got confidence in asking or answering at least simple questions. Third and the important result is the cognitive level was improved much more for average students and a little for top performers, which is the basic goal of an active learning pedagogy. Also, the outcomes of the course listed as in section 3 were achieved which is the main goal of teachers. Overall, the defined approach underpins the vital idea in students that mathematics and programming in engineering and technology are well knotted in the modern world.

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