Journal of Engineering Education Transformations,
Volume No 36, January 2023, Special issue, eISSN 2394-1707

10.16920/jeet/2023/v36is2/23079

Multicore Architecture and Programming: A Collaborative teaching with Industry for empowering students with industry skills

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***Abstract*— This paper presents the experiences and outcomes of teaching an elective course Multicore Architecture and Programming (MCAP) with an automotive industry- (Bosch Global Software Solutions, Bangalore, (BGSW).The practices and outcomes of the course for two different batches with two different modes of delivery, the online and physical mode are discussed. MCAP is a course which deals with higher levels of embedded systems concepts; hence for an effective learning and also to impart industry experiences, we adapted a co-design, co-delivery and co-assessment with industry. The course is designed involving core concepts of MCAP, hands-on sessions, and also industry use cases. The delivery of the course is planned with both regular lectures by instructors and industry experts. The assessment was done for the hands-on sessions, higher cognitive level assignments and through end semester exams. The assignments were designed with the help of industry to assess higher cognitive level learning. The delivery and assessment happened in online for the first batch and in physical for the second batch. The outcomes of the course for both the batches were convincing, with the students readiness of having skills applied to embedded industry and concept learning. The students showed a lot of interest and enthusiasm to learn throughout the course, and this resulted in most of the students getting placed in automotive/embedded industry. Few students with interest further continued in the same area and have taken higher semester projects, internships and placements in the same area which aided them to choose their career ahead.**

Keywords: **Industry-academia collaboration, co-teaching, co-design and delivery, higher cognitive assessment**

***JEET Category*— Research**

I. INTRODUCTION

Designing a higher semester course for engineering students is challenging, as the students will be more focused towards their placements. The introduction of courses which are industry relevant or incorporating industry skills in the design and delivery courses will aid the students' interest and also will help students to get placed in the industries. Considering the interest of building industry specific skills among students, the course on MCAP is introduced for sixth semester students of Electronics and communication engineering, in collaboration with BGSW[13].

Prior to the course MCAP, the students were introduced to basics of embedded systems, programming and also an application-based course, automotive electronics in collaboration with BGSW is also introduced in the same semester[4]. MCAP course had a concept related to multicore architectures and also parallel programming with code optimization; hence course had a weightage for theory (2 credits) and hands-on learning (1 credit). The industry (BGSW) was involved in all stages of course design and delivery.

The uniqueness of the course was about having i) Integrated course structure with both reasonable weightage for theory and laboratory concepts. ii) Course contents designed with the industry inputs iii) Co-teaching, with the contributions from industry and academia during delivery of the course iv) Industry use case implementation having higher cognitive assessment v) Co-assessment, evaluation of the course at multiple levels by both industry and academia vi) Rewards by industry after successful completion of the course.

In this paper, the authors have shared their experience of design, delivery and outcomes of the course for online and physical mode[1].

The next section on methodology discusses the course objectives and strategies adapted in a systematic way; later we discuss assessment methods for both online and physical mode of delivery, use case implementation assessment to evaluate higher cognitive learning and industry reviews[2]. Then we discuss outcomes of the course in terms of student feedback, industry feedback and student placements[3]. Finally, we conclude by summarizing overall experience of handling this course.

II. METHODOLOGY

Multicore & Embedded systems curriculum is expected teach and train students to design complex and heterogeneous embedded computing system meeting industrially relevant design challenges[10]. Teaching embedded systems as an integrated topic is a difficult task since it can be very diverse and multidisciplinary, ranging from micro-controller basics and real-time concepts to hardware/software co-design, distributed processing, reconfigurable computing, and system-level architecture design. This course was designed as a Collaborative Course in the Engineering Curriculum has endured the emphasis for the engineering educators and frequent efforts have been seen in this zone.

A. Multicore Architecture & Programming Course Design & Delivery

This course was designed as a Collaborative Course in the Engineering Curriculum has endured the emphasis for the engineering educators and frequent efforts have been seen in this zone[11]. This course is introduced in our Curriculum at the sixth semester level in order to familiarize about the concepts related to the increase in efficiency of the processor such as pipelining and superscalar design. It also provides an overview of understanding about the modern multicore architectures. Students will acquire the knowledge about the conceptions and methods for writing the CPU multithreaded programs through the use of threading & synchronization primitives[5]. One of the main emphasis was given to the Code Optimization. Students will also learn about the various programming procedures such as SIMD instructions, removal of branches & loop unrolling methods.

This elective course is conducted by the faculty along with the BGSW team. It is engaged by the faculty continuously for two years. The description of the mode of this course conduction is as follows. It has been described in the form of two phases.

Phase 1:- Implementation Of On-line mode of teaching

Nobody has ever made a forecast for the pandemic situation in 2020. It will have long-lasting impacts. Today's online users have a tendency to say too much. Every single one of us was surprised by COVID-19. COVID-19 had a devastating impact on the education industry. There is a need to rethink, reform and reinvent the educational system immediately. There is currently no substitute for online learning.
COVID-19 had a devastating impact on the education industry. We need to rethink, reform, and reinvent the educational system immediately. At the moment, there is no substitute for online education. Online education offers a useful substitute for traditional classroom instruction. The finest learning occurs when students interact with their teachers & peers. During online instruction, students communicate what they have learned. In general, students are seen to get used to online instruction. This course was designed by KLETU in collaboration with RBEI as an initiative to build Center of Excellence(CoE) in Cross Domain Software Development(CDS) platform.

The Objectives of CDS-CoE are as follows

- Addition of new courses related to CDS with the support from Bosch team
- RBEI to train the faculty & students for better handholding
- RBEI to give problem statements, so that students & faculty members will deliver productive & employable results.

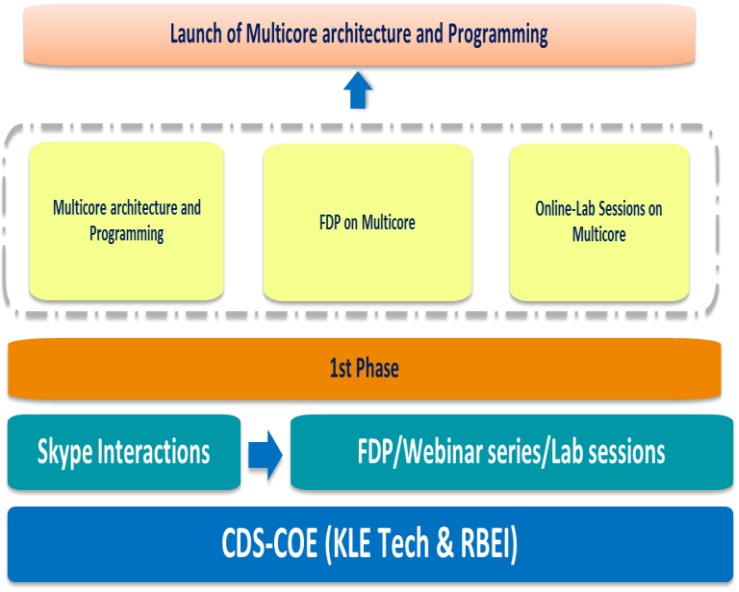


Fig 1. Workplan Of CDS-CoE

The work plan of the CDS-CoE is shown in the figure 1. This course was launched in the year 2020. Faculty Development Programs, Webinars and online lab sessions on multicore were conducted to the faculty by RBEI team. In order to finalize with the syllabus, various skype interactions or discussions were happened. Thus, The MCAP course was thus born with the following course outcomes.
At the end of the course, the student should be able to

1. Illustrate the challenges in parallel and multithreaded programming.
2.Explore the various parallel programming paradigms and solutions.
3.Implement the algorithms using MPI, Open MP, pthreads, CUDA or a combination of these.
4.Analyze the parallel programming implementations for timing, schedulability performances.

Each course outcome relates to their specific units(chapter wise). These course outcomes will be related to the chapter wise questions examined in the ISA as well as ESA.

With the help of interactions, finally we had come up with the plan of co-teaching and content delivery by KLETECH Faculty & RBEI Experts which is presented in the form of TABLE I. Initially, this course was imparted by the faculty and BGSW team in online mode.

TABLE I.
Co-teaching and delivery by KLETECH Faculty & RBEI Experts

Sl.No	Topic	Content (Lectures +Practical)	KLETECH faculty	RBEI Team
1.	Introduction to Multicore with Hands-on Introduction to OpenMp	04+04hours	06 hours by KLE Tech faculty Theory and Lab Sessions	2 hours by RBEI 10.00 – 12.00 (Theory discussion, Q&A)
2.	Memory access in Multicore architectures and Hands-on using Multicore evaluation boards	05 Hrs	KLE Tech faculty Theory and Lab Sessions	Support by RBEI team
4.	Scheduling concepts and OS aspects Hands-on using Multicore evaluation boards	06 Hrs	KLE Tech faculty Theory and Lab Sessions	Support by RBEI team
5.	Concurrency and Parallelism Hands-on using Multicore evaluation boards	06 Hrs	KLE Tech faculty Theory and Lab Sessions	Support by RBEI team
6.	Synchronization primitives Hands-on using Multicore evaluation boards	05 Hrs	KLE Tech faculty Theory and Lab Sessions	Support by RBEI team
7.	Advanced Multicore topics	06 Hrs	KLE Tech faculty Theory and Lab Sessions	2 hours by RBEI team

Several theory and hands-on practical sessions were engaged by BGSW team to the faculty as well as to the students in order to make them understand about the usage of multicore concepts and its applications. The co-teaching and delivery plan represents the topics and the number of content hours engaged by the KLETU and RBEI team. The course was delivered as per this plan. Students have explored the multicore concepts using Open-MP. Thus, it can be said that it was a great experience teaching this kind of collaborative course in on-line mode.

Phase 2:- Implementation of Off-line mode of teaching

The same course content was delivered in the Off-line mode. The co-teaching and delivery by KLETECH Faculty & RBEI Experts remains the same for this mode. Conventional way of teaching using chalk & talk method was followed in this mode. As usual several theory and hands-on practical sessions were engaged by BGSW team to the faculty as well as to the students. The only drastic change that was bought into this mode is introducing the students to the higher cognitive level of questions. The same software, Open-MP was explored by the students even in this mode of teaching for performing the hands-on session.

III. ASSESSMENT

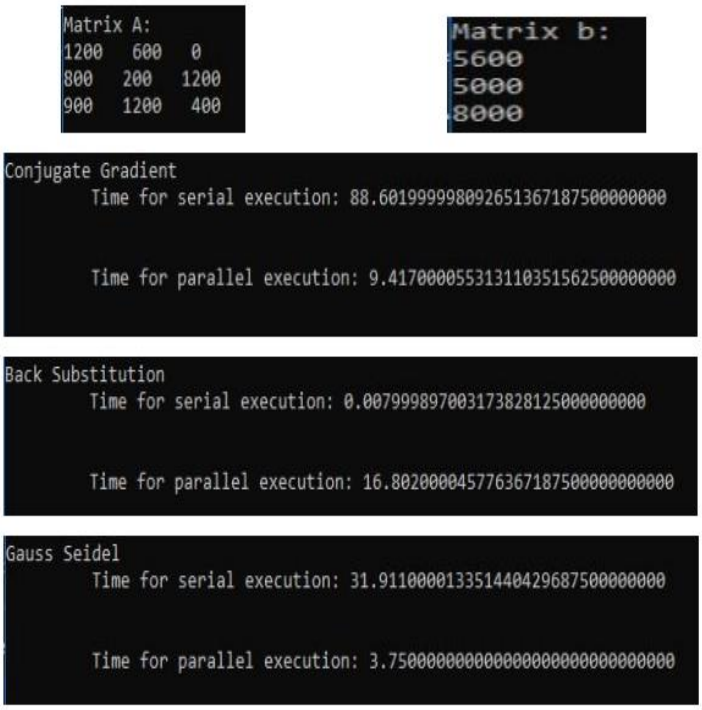
The development of rubrics for assessment activities that are aligned with module and course outcomes is the first step in assessment planning[6]. Throughout the course, it is customary to explain the assessment criteria to students before the assessment activity begins. As a result, students' performances have improved, and the assessment system has gained their faith and trust. On a few cases, procedures for self and peer assessment are also used. The assessment methods of the activity was carried in the form of two segments. The first segment was evaluated in the form of writing In Semester Assessment and End Semester Assessment. Equal amount of weightage was given to ISA as well as ESA. The second segment was evaluated in the form of assignments (writing and executing the programs using OpenMP) and solving the higher level cognitive questions. The assessment methods of the activity included the students contribution solving individually and in team. The assessment criteria remained the same for these two consecutive years except the change in the evaluation of higher level cognitive questions.

A. Implementation segment of the Course Project

TABLE II.
Sample Questions

SL NO	Sample Questions
1)	A manager of a factory consisting of ‘m’ workers working for ‘n’ days, wants to know the duration for which each of them are working in one day, based on the salary paid to them. The manager is frustrated, as the system he was using consumed more time to compute the time for which each worker was working. To help him in calculating the time of work of the workers, design and implement a code which is time efficient and makes use the resources available for computing to it’s best. Analyze and show how the presented code is better than the traditional code.
2)	In Automotive world, segmentation play's a very important role. To make use of segmentation by using Region Growing algorithm which includes lots of computations in finding distances. Design and implement a code to solve such computations, making efficient use of the available parallel computing platform OPENMP. Analyze the implementation for speedup and overhead for Region Growing algorithm computation & also determine the optimal implementation

The TABLE II represents the sample questions framed by the students for course project depending upon the themes given by the faculty.



Method	Time For Serial	Time for 2 threads	Time for 4 threads	Time for 6 threads
Back Substitution	0.0009	4.209	3.466	4.5144
Conjugate Gradient	13.3119	5.421	2.2010	1.8410
Gauss Seidel	45.6099	2.5810	2.4789	2.1156
Formula Method	0.008	0.006	0.004	0.003

Fig 2. Results for the first & second sample question

The figure 2 and 3 characterizes about the results of Course Projects for the sample questions discussed in the table 2. Figure 2 portrays about developing a serial and parallel program which can determine the solution for the set of linear equations and its analyses. Figure 3 depicts about developing a parallel program to implement various computations of distances from the seed node to the all other nodes involved in segmentation by using region growing algorithm and hence the execution time is being decreased which intern boosted up the perfomance.

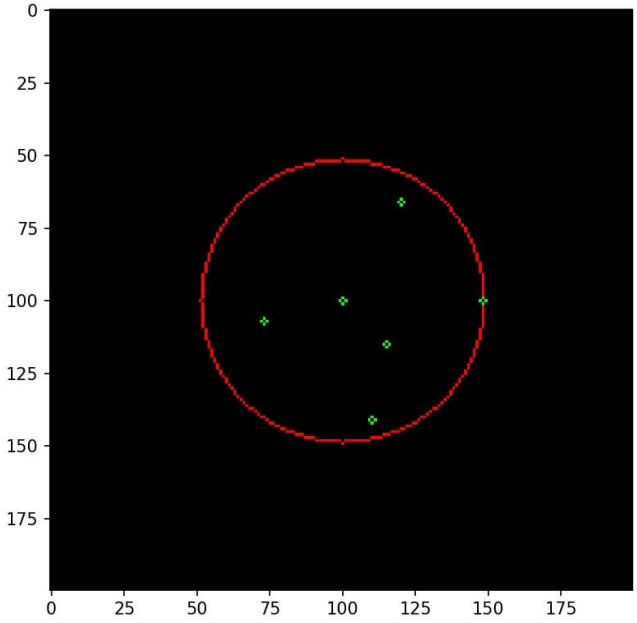


Fig 3. Result for the second sample question

B. Process of Assessment

The process of assessment discussion is as follows

TABLE III
Assessment Criteria

SLNO	Assessment Criteria	Weightage
1	In Semester Assessment	40%
2	Course Project	60%

The TABLE III represents about the assessment criteria that was carried out for this course. The assessment criteria discusses about Two minor exams were conducted for this course which included the higher level questions(Level II & III). Each minor was written by the students for 40 marks which was further deducted to 15 marks. The programming assignments(higher level cognitive questions) were carried out using Open MP. Nearly 50% of the marks were assigned to these kind of assignments.

TABLE IV
Evaluation Rubrics

CO	Criteria	PI
Describe the implementation of application program on ARM9 /	Identify the system inputs and outputs	2.1.2
	Identify the system sub modules	2.2.1
	Identify constraints and limitation of the given problem	2.2.3
	Identify suitable programming approach	4.1.3
	Selection of proper algorithm to realize desired sub system	4.2.1
	Apply suitable tool chain	5.2.2

	Analyse results for possible test conditions	2.4.2
	Effective demonstration in a team	9.2.1
	Effective presentation	10.2.2
	Report writing	10.1.2

The evaluation rubrics is shown in the TABLE IV. They have been mapped to their respective performance indicators. Almost three reviews were conducted for the students, each team consisting of four members. Review 1 and 2 were assessed for 20 marks and review 3 were assessed for 10 marks. Finally, Course Project was evaluated for 50 marks. All course project reviews employ the practice of team reviews. Three reviews were conducted for the students by the faculty as well as RBEI team. Valuable Inputs were provided to the students in order to work on the course projects. Thus, the final outcome was achieved through these continuous review process. This practice has demonstrated significant benefits in terms of i) Instructors gaining knowledge from the industries to learn about the concepts through the applications. ii) students receiving the feedback from the industry perspective, which has led to improvement in their course projects. Finally, the collaborative course certificates were issued by the RBEI team to the faculty as well as to the students for the completion of the course successfully.

IV. Experimental Outcomes & Discussion

The effectiveness of this course was evaluated by considering different kind of measuring parameters[8]. Initially as per the outcome based education (OBE) all the course outcomes and questions related to this method were aligned to the competency program outcomes (PO) mentioned in the ABET criteria [9]. The results obtained demonstrated the areas of further improvements and also showed that learners are truly benefitted as they were able to solve good real problems through the concepts learnt. This activity provided a learning platform for the facilitators and students[10]. The level of questions pertaining to bloom's taxonomy [8] of Level 3 which relates to applying concepts to solve problems and programming analysis related to problem solving outcome PO2 was increased in question paper by 10% compared to the previous year. The activity was assessed by taking student feedback that included questions related to quality of training faculty competency in the course and active engagement of the class for which around 80% of the students strongly agreed that this method benefitted them in learning the course effectively. Thus, the authors were able to achieve 1, 2, 9 and 12 program outcomes corresponding to ABET [6], [7].

TABLE V
Experimental Outcomes

Student's Feedback	Areas Of Improvement
✓ Good way of learning the concepts	✓ More detailed explanation of concepts
✓ Revisit to the topics in class	✓ Giving some real world examples
✓ The approach towards teaching is good	✓ Make it more engaging
✓ Faculty is knowledgeable and has good teaching skills	✓ More animation or video effects in presentations are expected to achieve my interest in improvisation

The TABLE V represents the student's feedback and the scope to improve upon teaching this course. Thus, there is a possibility of enhancing the teaching of this course concepts.

V. Conclusion

The objective of imparting this collaborative course to the students addressing large classroom was strongly achieved. This activity promoted a platform to have better time management and plan informative interacting sessions. A dedicated feedback was taken by the students and as a result more than 90% of them have evidently remarked this course has helped them to stitch between evaluation, draw conclusions on the way of writing programs which in turn improved their logical and conceptual learning techniques. By introducing this system, the same course attained PO's 1, 2, 9 and 12. Thus, the outcomes of the course for both the batches were convincing, with the students readiness of having skills applied to embedded industry and learning. This approach has improved the performance and response of students in teaching and learning. Students showed a lot of interest and enthusiasm to learn throughout the course, and this resulted in most of the students getting placed in automotive/embedded industry.

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