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Enabling Industry skills in Automotive Embedded Systems Courses: A Collaborative Model

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***Abstract*— Automotive electronics and related software market is growing significantly and expected to gain high demand of skilled employees in the next decade. The market drivers being the customer preferences, government regulations, technology adoption and recent participants like autonomous and electric vehicle technologies. Hence, industries are showing lot of interest in collaborations with academia for technology innovations and for getting industry ready employees. This paper presents the experiences and outcomes of collaborations with automotive industries in automotive embedded systems courses like, Automotive electronics, AUTOSAR, Multicore core architecture and programming, and Human-Machine-Interface offered to the students of Electronics and Communication Engineering program at KLE Technological University. These courses involve core technical concepts, computing, and design of hardware/ software architecture. The traditional mode of teaching is found to be less effective and hence, innovative pedagogical techniques are used with the help of industries for teaching these courses. The techniques helped to enhance students' ability to solve complex engineering problems and to build higher cognitive learning ability. The collaborative contributions from both industry experts and academic faculty in design and delivery of automotive embedded courses have resulted in building industry specific skills among students which in turn resulted into a greater number of in campus placements and reduction in on job training.**

***Keywords*— Automotive Embedded Systems, Industry collaboration, Complex engineering problems, Higher cognitive learning, Industry Ready**

I. INTRODUCTION

Automotive industry is the sixth largest economy in the world. It is continuously growing and the growth is enabled mostly by the technology innovations happening in the core areas of electronics and computing. Every new feature introduced in today's car is assisted by E/E systems and related software. Hence, the cost for the electronics the customers is paying for an automobile is increasing every day (Nissimagoudar, 2016). These evolutionary changes in the automobile industry have made the car manufacturers and other tier 1 suppliers to look towards academia for new innovations and industry ready students (Pillai, 2023). At our organization, we have a strong collaboration with automotive industries like BGSW, KPIT, Continental, Mercedes Benz, Vector and many more since a decade. BGSW amongst these leads the list. The collaborations are towards, curriculum design, laboratory set up, expert sessions and vehicle demos for the automotive embedded systems courses (Nissimagoudar, 2016). The collaborations are getting stronger every year, which in turn provide students with ready skills for the industry. The university is getting maximum on campus placements for its students and industry are benefitted by getting employees who can be put directly on the job (Nissimagoudar, 2015). In this paper we are discussing how these collaborations helped to structure the courses which are multidisciplinary and also application oriented were co-designed, co-delivered and co-assessed for enhancing students' learning abilities and also for empowering them with the industry ready skills (Nissimagoudar, 2020). The paper mainly focusses on two courses, the Automotive electronics which mainly deals with building electronic systems for mechanical systems and Multicore architecture and programming, which deals with computational skills required for designing automotive software. Both of these courses were offered to the students of Electronics and Communication Engineering (ECE) program. We discuss how the contributions from BGSW has strengthened these courses. Section I introduces the topic and discusses the motivation for getting industry flavor for the automotive embedded systems courses. Section II discusses background for the topic in terms of significance, necessity and expectations from the collaborations towards the courses. Section III discusses the methodology adopted for automotive electronics and multicore architecture and programming courses in terms of course design, delivery and the activities designed to enhance the student learning. Section IV discusses the implementation details by taking example use cases. Section V discusses the outcomes and section VI concludes the topic and also discusses the future strategies.

II. BACKGROUND

KLE Technological University practices many innovative practices for making student learning effective and for preparing students industry ready (Iyer, 2020). The University is one of the national leaders in engineering education. Amongst the many initiatives one of them is introducing industry relevant courses in the curriculum and also revising the courses regularly to address latest developments in industry. One of the major tier 1 suppliers, BGSW, and then known as Robert Bosch Engineering Solutions (RBEI) collaborated with our organization around ten years ago for the automotive electronics (Nissimagoudar, 2020). This collaboration extended from introducing the course as an elective, then converted as core course, later the introduction of course projects and

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laboratory component. Further the other related courses like AUTOSAR and recently MCAP and HMI added the list. Through this paper we share the experiences and outcomes of this collaboration. Along with designing the curriculum the industries contributed by providing use cases, statement of work and problem statements for students work as part of the course and also the industries involved in regular reviews and assessment. This exposure helped the students to gain industrial experiences.

III. METHODOLOGY

The automotive electronics and multicore architecture and programming curriculum deals with preparing students get exposure to design complex automotive sub systems involving heterogeneous computing platforms meeting industry standards (Patil, 2023). Teaching these courses focusing the theoretical concepts and laboratory exercises is less effective. Both of these courses deal with multidisciplinary topics ranging from mechanical concepts to electronic solutions for automotive electronics and for MCAP from microcontroller concepts to distributed computing concepts. The industry flavor for these courses aids higher level learning for the students which in turn make them ready to solve complex engineering problems. The embedded steam of ECE has core embedded courses at the lower semesters and at higher semesters embedded systems applications-oriented courses are offered to the students with the industry support (Figure 1).

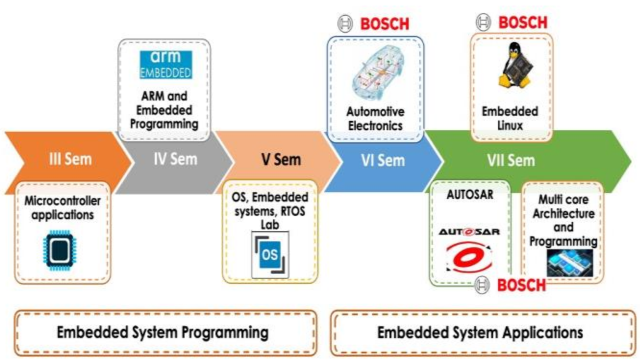

Figure 1: Vertical based curriculum design: Embedded Systems

The automotive electronics course is highly multidisciplinary, it involves designing embedded systems for automotives. The addition of every new feature in to the car is enabled by electronics and related software (Sony, 2020). The continuous involvement of BGSW makes the course better every year. The curriculum is designed involving BGSW experts and KLE faculty. The course contains along with conceptual electronics for automotives, very latest topics relevant to automotive industry.

The course contains V design model, very specific to automotive industry, the concepts of Model Based Design (MBD), concepts of electric and hybrid vehicle designs, automotive communication protocols, functional safety standards-ISO26262, and diagnostics. These concepts require more of industrial use cases to implement and industry mentoring. Hence, the structure of entire automotive electronics course is co-designed with industry depicted in Figure 2.

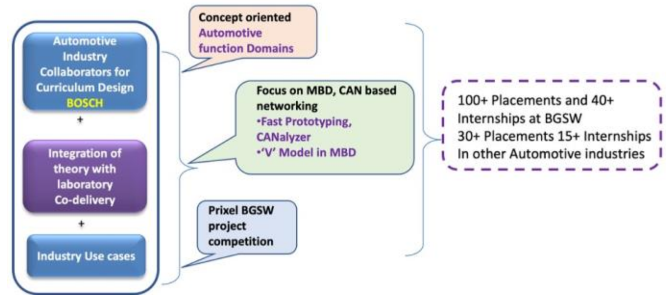

Figure 2: Automotive Electronics course structure

The different components of automotive electronics course are, • Course contents designed by BGSW and KLE Tech faculty • Course delivery: Integration of theoretical concepts with laboratory exercises – Co-delivery from BGSW experts and KLE faculty – Vehicle demo • Course activity: Use case implementation (PRIXEL, the Prime Excellence Program by BGSW) This strategy has resulted in students getting exposure to various skills required for automotive industries like MDB, fast prototyping, and V design model which in turn resulted in placements and internships at core automotive industries. The Multicore Architecture and Programming (MCAP) was developed in collaboration with Bosch Global Software Solutions (BGSW) with goal of enhancing student knowledge and to meet industry requirements (Kamble, 2021). The course is an initiative of Bosch Centre of Excellence for Cross Domain Software (CDS CoE). The objective of the initiative was, RBEI to train the faculty and students for better hand holding and RBEI to give problem statements, so that students and faculty members will deliver productive and employable results. The course has an activity requiring students to analyze and develop solutions for complex engineering problems with the aim of enabling higher cognitive level learning among students. The activity involved sequential and parallel implementation of the software with code optimization. The course structure is as follows, • Course design: Collaborative design involving both academic and industry representations – Focus: Embedded Multicore, Code Optimization, Automotive context • Course delivery: Online sessions by BGSW, Class-room sessions by KLE Tech faculty. – Integration of theory and practical sessions. – Industrial use case discussion by BGSW. – Problem formulation for use-case implementation to measure higher cognitive learning by KLE Tech-and BGSW teams. – Co-Assessment • Internship opportunities at BGSW also Certificates by BGSW for faculty and students. The course structure is shown in figure 3.

IV. IMPLEMENTATION

The automotive electronics and MCAP courses are offered to the students during sixth semester of ECE program. The students had a prior background of basic embedded courses like, 8051 microcontroller architecture and programming, ARM processor and its applications, Operating Systems and Embedded systems design. Both of the Automotive embedded systems require the knowledge of basic embedded courses. The automotive electronics course was offered to students as core course as it involves core concepts of automotive embedded systems. The course was delivered to the students in an integrated manner, wherein the concepts and related practical implementations were taught together at the same time. The practical implementations were done using MBD, one of the popular styles used in industry for rapid prototyping. The course implementation flow is demonstrated as shown in figure 3.

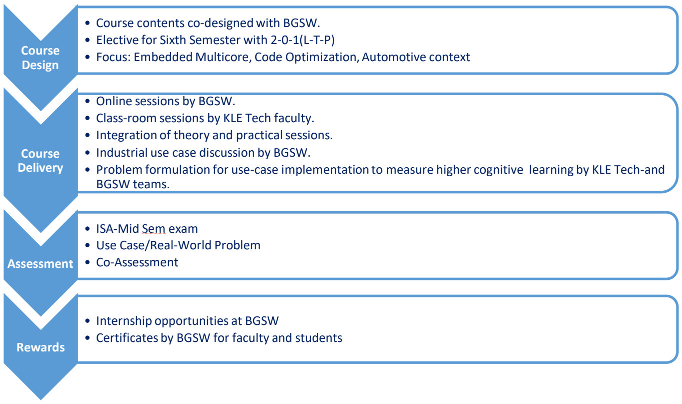

Figure 3: Automotive Electronics course structure

TABLE I
AUTOMOTIVE ELECTRONICS COURSE IMPLEMENTATION

Theoretical Topics Addressed	**Practical Demonstration**
Automotive Mechanical Systems	Demonstration using cut section modules
Engine Management System, Automotive safety systems, Automotive sensors and automotive industry practices	Model-in-the-loop(MIL), Software in the loop(SIL)
Automotive Communication Protocols	CAN cluster implementation
Functional safety ISO 26262 and Diagnostics	Use case implementation
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The BGSW and KLE Tech both the teams were involved in designing the demonstration uses cases and practical implementations. Some of the use cases are shown in TABLE II. The requirements, mathematical model and Simulink model for one of the case study is shown in figure 5. The integrated experience of concepts and practical built a strong foundation for the course and the students were prepared to take-up problem statements given by the industry. BGSW proposed an event named as Prixel-Primary excellence program, wherein students were given a industrial use case for implementation. The teams were encouraged to take up problem statements and

TABLE II
USE CASES AND PRACTICLE IMPLEMENTATIONS

Use Cases	**Learning Outcomes**
1. Modeling and simulation of a vehicle motion on a flat surface during hard acceleration, deceleration and steady acceleration.	• Model and simulate the vehicle motion for the driver's desired load and analyze the results.
2.EGAS modeling and simulation on the hardware platform.	• Explain the sensors and actuator functioning to EGAS. • Model and simulate the sensors, actuators and control algorithm. • Generate C-code for the target hardware to realize the functionalities.
3. Modeling and simulation of the Fuel Control System and realization on the hardware platform.	• Model and simulate the vehicle motion for the driver's desired load and analyze the results.
4. Modeling and simulation of an Anti-Lock Braking System and realization on the hardware platform.	• Explain the sensors and actuator functioning to EGAS. • Model and simulate the sensors, actuators and control algorithm. • Generate C-code for the target hardware to realize the functionalities
5. Gear input transmission over CAN bus using ARM Cortex M3 and signal analysis using CANalyzer/BusMaster software. Code driven and Model driven integration for Vehicle speed control function based on the gear input.	• Establish CAN network using ARM Cortex M3. • Explore automotive protocol tools such as CANalyzer/Busmaster to analyze the CAN signals.
6.Design and develop Adaptive Cruise Control (ACC) system using MBD approach.	• Model sensors/actuators/control algorithms. • Perform MIL,SIL,PIL • Generate C-code from the model to deploy onto the target hardware.

mentoring was done by both BGSW team and KLE faculty. Some of the problem statements are as follows, • Camera based vehicle functions – Detecting speed breakers on Indian roads (Marked/Unmarked, Standard/Non-standard) – Detecting Road hazards like potholes, bad roads etc. • Connected Vehicles – V2X communication

-Derive a creative solution around the connected vehicles area and implement a proof of concept.
– Decide on a wireless communication technology (Wi-Fi/GPRS) and a lightweight protocol to use for communication
• Secure OTA updates – Derive a proof of concept for verification of Software download before updating vehicle computers / Electronic Control units
– Cryptography algorithms
– Consider the execution time/ resources while considering the solution

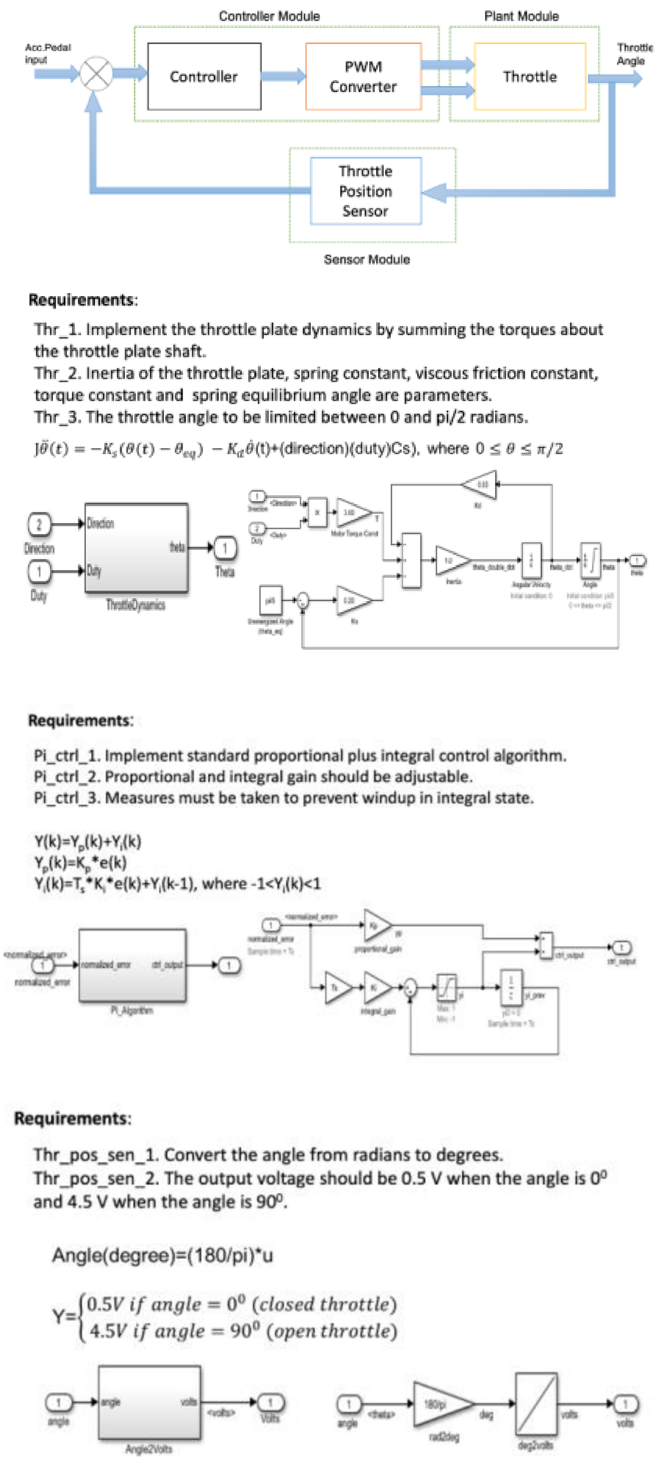

Figure 5. The requirements, mathematical model and Simulink model for EGAS

Detection of vacant parking slot/space using computer vision/image processing

– The algorithm/model will be designed for detecting parking slot from around view images.

– The co-ordinates of parking slot shall be calculated with respect to vehicle Centre.

Surround view image dataset will be taken from publicly available dataset. Around 60 teams from KLE Tech participated. This activity had a Maximum Participation from KLE TECH KLE Tech teams were among top Five Teams. Three teams completed the project and presented their topic to technical experts. This exposure gave students an experience of working with industries. Also the finalists in the event got an internship offer from BGSW. MCAP is offered to students as an elective. The intention was to offer this course to students, who wish to pursue their carrier in automotive embedded systems domain. The role of BGSW was significant in delivering this course to students. As this course is offered at higher semester, the goal was also to imbibe higher cognitive learning ability to students.

TABLE III
ATTRIBUTES OF COMPLEX ENGINEERING PROBLEMS

Attributes and Bloom's Level	Cognitive Process Dimensions	Description
Cannot be resolved without in depth engineering knowledge(L4)	Select, Differentiate	Knowledge of evaluation criteria, and Ability to evaluate choices made. • Architecture • Performance models and analysis • Programming patters • Algorithms • Tools
Have no obvious solution and require abstract thinking and originality in analysis to formulate suitable model(L5)	Determine, Judge	Computing platforms and algorithms need to be compared and the choices should be justified • Hardware, operating systems, Languages, compilers, tools • Granularities of parallelism • Parallel operating system
Involve infrequently encountered issues(L4)	Determine, Judge	Perceive the importance of objectives and prioritize. • Dependencies • Synchronization and concurrency • Resource allocation • Data access and communication • Performance and scalability
High level problems including many component parts or sub problems(L4)	Differentiate, Integrate	Differentiate the objectives • Decomposition to independent tasks • Assignment of tasks to multiple processors.

The outcomes expected out of this course are,

- Discuss the need for multicore architecture (L2).
- Analyze and identify the challenges in parallel and multithreaded programming (L4)
- Explain the various parallel programming paradigms and solutions (L2).
- Implement algorithms using standard parallel programming APIs (L3).
- Analyze parallel programming implementations for performance metrics (timing, scalability, speedup, schedulability, and performances) (L4).
- Develop solutions for given problem using optimal

algorithms and libraries (L4).

Along with learning concepts related to multicore architecture, which addressed Bloom's learning level 2, the use case implementation assignments provided by BGSW helped to address higher Bloom's level learning (Level 3 and Level 4). The use case implementations had attributes, which are shown in the TABLE III. The example use case implementations are shown in figure 6 and 7.

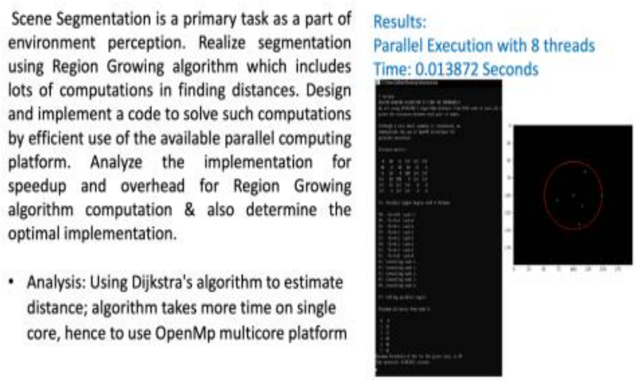

Figure 6. The Example use case: Scene segmentation

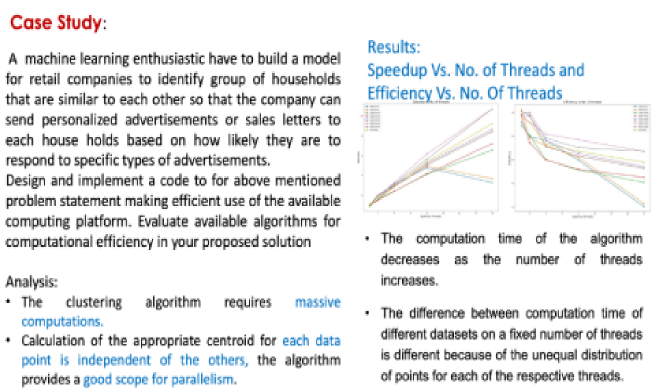

Figure 7. The Example use case: Machine learning problem

The use cases and the related real-world problem are implemented in two main stages, Problem Analysis and Implementation. Each stage deals with,

• Analysis
  - Justification for choosing the said algorithm
  – Parallelization: Speed up/fraction enhanced
  – Modularization and optimization
• Implementation
  – Computing platform:
    ∗ OpenMP on general purpose machine,
    ∗ Heterogonous computing platform (GPU, TPU, accelerator), ∗ Embedded multicore platform.
    ∗ Resource utilization analysis

The MACAP activities enhanced the higher cognitive learning abilities of the students, and also gave the exposure to solve the industrial problem statements.

V. OUTCOMES AND DISCUSSION

The industry involvement in the automotive embedded courses enhanced the student learning in multiple ways and also benefitted the industry in turn by providing them industry ready employees. Benefits to Academic /Research:

- Engagement with a wider research/industry community who are working on real problems.
- Integral engagement with leading industrial partners in both training and research.
- Industrial professionals share their expertise and work behavior with students giving them a comprehensive outlook on professional work.
- Help students find relevancy between theoretical and practical approaches. Benefits to Industry Partners:
- Receive a recent graduate working on industrially relevant problems.
- Semester-wide 'interview' to choose students with required skills.
- Cut short their recruitment process by hiring the students they are already working in collaboration with.

Technical and professional competencies achieved as per the ABET outcomes are,
The Technical outcomes (2, 3, 5),

- Structured approach to parallel programming.
- Strategies needed for writing efficient, scalable programs.
- Embedded system design flow
- Modular software development
- Handling multiple files during software development
- Integration of modules
- Porting of applications to different platforms
- Working with different tools

The Professional outcomes (9, 10, 12),

- Industry experience
- Deadline management
- Project Management
- Present trends in industries

The outcomes in terms of placements and internship offers from industry are as shown in TABLE IV.

VI. CONCLUSION

The collaborative framework proposed is beneficial for both academia and industry. The two application oriented courses are taught during higher semesters had an integrated course structure with reasonable weightage for theory and laboratory concepts. The courses were designed with the inputs from industry and co-teaching was practiced during delivery of the course. Students were given an exposure to the automotive industry practices like MBD and rapid prototyping, and also got a hands-on experience of using automotive grade hardware and programming the same. The use cases provided by industry helped the students to get an exposure to solving industry level problems and also to attain higher cognitive level learning. The students were prepared to solve complex engineering problems.

TABLE IV
PLACEMENTS AND INTERNSHIP OFFERS

2021-22	Automotive Electronics	MCAP
Number of students registered	300	49
Bosch Certification	--	49
Placed in Automotive /Embedded industry (BOSCH/Mercedes Benz/Continental/Infineon)	150+	3
Internship offered (BOSCH/Mercedes Benz/Continental/Infineon)	60+	15

The major outcomes were the student placements and internship offers in core embedded industries for academia and the industries getting employees who can be put directly on job.

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