Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-1707

Fostering Higher Cognitive Skills Through Industry Collaboration: A Microcontroller-Based Approach

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***Abstract*— This paper presents an innovative approach to enhance higher cognitive skills in students through collaboration with the industry, focusing on microcontroller education. In the fast-evolving landscape of technology, bridging the gap between academia and industry is paramount. Our paper describes a course activity that leverages industry collaboration to impart critical thinking, problem-solving, and knowledge application skills to students.**

The course activity centers on the in-depth study of the Atmega32 microcontroller, chosen for its industry relevance and rich feature set. Students delve into fundamental concepts, architecture, programming, timers, counters, interrupts, and peripheral integration. They are encouraged to apply their knowledge to real-world scenarios through hands-on projects (Bolanakis, 2019)

Key components of this approach include industry mentorship, project-based learning and formative assessment. Industry professionals guide students in solving industry-related challenges, fostering creativity and practical problem-solving. Continuous evaluation assesses students' critical thinking, knowledge application, and problem-solving abilities.

The paper demonstrates the positive impact of this collaborative learning approach on students' cognitive skills and their preparedness for real-world industry roles. By adapting theoretical knowledge to address industry needs and aligning with best practices, students gain valuable skills essential for success in the technology-driven job market.

***Keywords*— Cognitive Skills; Critical Thinking; Industry Collaboration; Knowledge Application; Problem-Solving**

***JEET Category*— Effective Industry-Academia Partnerships in Engineering Education**

I. MOTIVATION

In the established curriculum of a Computer Science undergraduate program, there are usually a couple of courses focused on hardware, beginning with foundational principles and progressing to the exploration of embedded systems. Nevertheless, the course instructors have observed a notable lack of enthusiasm among students when it comes to engaging with these hardware-oriented courses. During their initial year in the program, students gain some exposure to interfacing peripherals with ARDUINO through the Engineering Exploration course (Nayak, Hiremath, Umadevi, Garagad, 2021). However, this introductory course primarily guides students in using pre-existing libraries for their project designs, rather than delving into the underlying architectural intricacies of the microcontroller employed in those projects. This necessitated the need to equip students with an in depth knowledge and understanding of the working of a microcontroller. The initial hurdle for the course teachers was to generate interest among students for these hardware-focused subjects. In response to this challenge, the authors embarked on a series of innovative approaches to make these courses captivating from the outset and subsequently align them with the needs of the undergraduate program.

II. BACKGROUND

The course on microcontroller for II year Computer Science undergraduate students underwent a comprehensive reformation process aimed at addressing the gaps observed in content, teaching methods and assessment strategies. The course instructors collaboratively engaged in brainstorming sessions to devise innovative approaches for tackling the identified challenges. As a result of this thorough review, several modifications were introduced.

This paper was submitted for review on September, 09, 2023. It was accepted on November, 15, 2023.
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The credits for the course are split into Lecture (L), Tutorial (T) and Practical (P), in short it is represented as L-T-P. Notably, the credit distribution (L-T-P) shifted from the previous 3-0-1 format to a more practical-oriented 1-0-3 format. The focus was thus shifted from lecture oriented content delivery to practical oriented hands-on approach (Bolanakis, 2019). The instructional methodology underwent a transformation from traditional to a more enriched approach, where students collaborated in teams and each team actively participated in addressing challenges presented during every laboratory session (Nayak, Hiremath, Umadevi, Garagad, 2021).The course instructors also recognized the significance of a well-designed assessment strategy in shaping the learning process (Almulla & Al-Rahmi, 2023). The assessment approach prioritized the evaluation of practical programming skills and the application of acquired knowledge, moving beyond traditional written examinations (Blackburn et al, 2018). The instructional approach was strategically adjusted to achieve a balance between theoretical knowledge and practical application. The foundational concepts encompassing microcontroller architecture and instruction set were delivered through one-hour per week theory classes. This provided students with the necessary conceptual grounding. Subsequently, the hands-on sessions assumed a prominent role, with a total of six hours allocated each week. These practical sessions were designed to allow students to actively engage with the subject matter. To enhance the collaborative and experiential aspects of learning, students were organized into teams during the laboratory sessions (Shettar, Nayak & Shettar, 2020).This team-based approach not only encouraged peer learning but also fostered teamwork and communication skills, which are crucial in real-world engineering scenarios.

III. LITERATURE SURVEY

The paper (Giannakopoulos, & Buckley, 2009) explores the interplay between problem-solving, critical thinking, creativity and knowledge management from a theoretical mathematics standpoint. The research investigates how these cognitive processes are interconnected and influence the way knowledge is created, organized, and utilized within an organization. The study provides valuable insights into the theoretical foundations of knowledge management, emphasizing the significance of cognitive skills in this context. The study by (Shehab & Nussbaum, 2015) investigates the cognitive load imposed on learners when they engage in critical thinking strategies. The research explores how different critical thinking activities and techniques affect cognitive load, which is the mental effort required to process information. The findings of the study contribute to our understanding of how to design instructional materials and activities that promote critical thinking while managing cognitive load effectively. In essence, the research sheds light on the cognitive demands associated with various critical thinking approaches. The paper (Blackburn, Villa-Marcos, Williams, 2018) explores the utilization of laboratory simulation software to better prepare students for practical sessions in various academic disciplines. The authors address the challenges associated with traditional practical sessions, which often involve resource constraints and limited access to equipment. The focus of the study is to enhance students' understanding and engagement by providing them with the opportunity to practice and learn in a simulated environment. The study conducted by (Wu, 2020) investigates the integration of Collaborative Problem Solving (CPS) techniques and cognitive tools to enhance higher-order cognitive processing in online discussion environments. The research focuses on how these approaches contribute to improving students' critical thinking and problem-solving skills within the context of online discussions. The paper (Rini, Adisyahputra, Sigit, 2020) explores the enhancement of students' critical thinking skills using a combination of Project Based Learning (PBL), motivation, and the Visual, Auditory, and Kinesthetic (VAK) learning style. Throughout the paper, they provide insights into the theoretical underpinnings of their approach, emphasizing the role of PBL in encouraging active engagement, problem-solving, and collaborative learning. The paper (Issa & Khataibeh, 2021) investigates the impact of utilizing Project Based Learning (PBL) on enhancing critical thinking skills among students, as perceived by teachers. By investigating the implementation and outcomes of PBL in the classroom. The authors shed light on the potential benefits of PBL in fostering students' ability to think critically, collaborate and solve problems effectively. The study conducted by (Kaczkó & Ostendorf, 2023) deals with the realm of critical thinking within the context of the Community of Inquiry framework. This research aims to provide an in-depth analysis of the theoretical model and cognitive presence coding schemes associated with critical thinking in online educational environments. In the article (Maries& Singh, 2023) talk about enhancing students' problem-solving skills within the educational context. This research aims to provide a concise review of the strategies, methodologies, and approaches employed to develop students' proficiency in problem-solving. In their study (Almulla & Al-Rahmi, 2023) investigate the interplay between social cognitive theory, problem-solving skills, critical thinking skills and their impact on sustainable learning performance. The study by (Bariroh, Triyanto, Fitriana, 2023) investigates the critical thinking ability of students in relation to their impulsive cognitive style.The primary objective of the study is to explore the relationship between students' impulsive cognitive style and their critical thinking ability in the context of learning the material related to two-variable linear equation systems. The impulsive cognitive style refers to individuals' tendencies to make quick decisions without thorough analysis, while critical thinking involves the ability to analyze, evaluate, and apply logical reasoning to solve complex problems.

IV. INTRODUCTION

The evolution of education in the field of microcontrollers has seen a transition from traditional classroom-based teaching to more dynamic and engaging methodologies. A prominent shift has been witnessed, where educators have realized the potential of fostering collaborative learning (Rini et al, 2020) environments to enhance students' understanding and application of complex concepts. This transition is particularly evident in the realm of microcontroller education, where the incorporation of team-based activities has taken center stage (Yusof, Ayob, Saad, Affandi & Hussain, 2020). This paper deals with the innovative approach of integrating team-based microcontroller activities into the curriculum, exploring how this method effectively promotes active learning, problem-solving skills and real-world applications. By investigating the intricacies of this pedagogical shift, we aim to shed light on the multifaceted benefits it brings to both students and educators, ultimately bridging the gap between theoretical knowledge and practical expertise. Incorporating industry-relevant case studies involving Atmega32 microcontrollers not only engages students in practical applications but also nurtures their creative and critical thinking abilities (Issa & Khataibeh, 2021). By challenging them with real-world problems, these case studies stimulate intellectual growth, empower students to approach challenges from multiple angles, and prepare them to tackle complex issues in their future careers. This necessitates an effective assessment strategy which addresses their technical and conceptual dimensions and measures the depth and breadth of their learning outcomes while preparing them for challenges in the area of embedded systems and beyond, which in turn leads us to think along the lines of the following research questions:

i. *How does incorporation of industry-academia collaboration encourage students to think creatively and critically about real-world applications, bridging the gap between theory and practice?*

ii. *How can the integration of Atmega32 microcontroller projects within a collaborative experiential learning environment lead to the development of higher cognitive skills, such as evaluating trade-off and justifying design decisions?*

To investigate the impact of industry-academia collaboration on students' creative and critical thinking while bridging the theory-practice gap, we implemented a multifaceted methodology. First, we established partnerships with industry professionals who provided real-world challenges and insights. To address the second question concerning higher cognitive skills, specifically trade-off evaluation and design justification, we integrated Atmega32 microcontroller projects into a collaborative experiential learning environment.

V. METHODOLOGY

Through this methodology, our study aimed to explore how industry collaboration inspires creativity and critical thinking while illustrating how Atmega32 projects can nurture higher cognitive skills, such as trade-off analysis and design justification, in a collaborative learning setting. This activity involves a shift from conventional teaching methods to a more hands-on and team-based approach (Zamarreño, 2021). Approximately two hundred and fifty, second year students of Computer Science & Engineering were made to work in teams to solve industry floated real-world problems. The focus was on experiential learning, (Bariroh, Triyanto, Fitriana, 2023) allowing students to gain a deeper understanding of higher cognitive skills (Wu, 2020), such as evaluating trade-off and justifying design decisions. The assessment strategy emphasizes knowledge application, creativity, critical thinking and collaborative team-work rather than traditional written exams.

A. *Content Design*

The course content was meticulously restructured into five modules, each comprising a coherent blend of theoretical instruction on the ATmega32 architecture and its corresponding instruction set, followed by hands-on implementation. This organized module structure facilitated a seamless transition between theory and practice, enabling students to solidify their understanding through practical application. In essence, the course overhaul resulted in a dynamic and immersive learning experience, emphasizing both theoretical comprehension and practical dexterity. The modifications introduced through collaborative efforts aimed to bridge the gap between theory and application, ensuring that students not only grasp the theoretical foundations but also acquire the hands-on skills essential for effective microcontroller programming (Udvaros, 2020). The architecture of a microcontroller plays a crucial role in determining its capabilities, performance, and suitability for various applications. Accordingly the course teachers divided the entire course content into five modules as depicted in Fig.1.

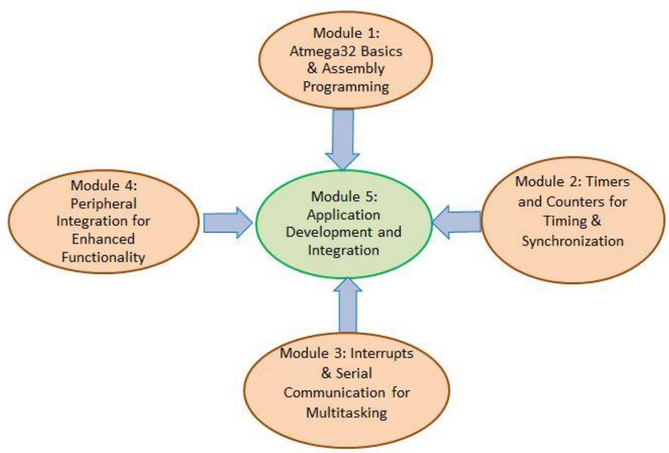


Fig.1: Course content at a glance

Module-1 consisted of fundamentals of Atmega32 architecture for strengthening basic concepts where the focus was on understanding the functionality and performance optimization. It also covered assembly programming. Students used Microchip AVR Studio as the integrated development environment (IDE) to write and execute the assembly programs. Module 2 encompasses Timers and counters that provide accurate timing and event synchronization. Module 3 deals with interrupts that allow microcontrollers to switch between different tasks or processes quickly. This facilitates multitasking, where the microcontroller can perform multiple functions concurrently without waiting for one task to complete before starting another. The module also covers interrupt-driven serial communication protocols, such as UART that allow data transmission without continuous processor involvement. This permits efficient data exchange between the microcontroller and external devices. Module 4 focuses on peripheral integration as it enables the microcontroller to interact with external devices, sensors, actuators and other components. It expands the capabilities of microcontrollers and allows them to perform a wide range of tasks and applications. Module 5 deals with achieving higher level of cognition by doing course activity that integrates knowledge from all the modules. Students developed applications based on the knowledge gained. Students effectively applied the knowledge and skills they acquired during the course to develop industry driven real-world applications. Some of the problems floated by industry were *Ultrasonic Radar Mode Using Microcontroller ATmega, RFID Based Attendance System, Android Phone-Controlled Robot among* others. This process involved utilizing their understanding of microcontroller architecture, programming techniques and various interfacing methods to create functional projects. By doing so, they not only reinforced their theoretical learning but also gained hands-on experience in solving practical problems using microcontrollers. This practical application of knowledge not only aims at enhancing their comprehension but also equips them with valuable skills that are directly applicable in the field of embedded systems and related industries.

B. Activity Planning

Recognizing the merit of industry relevant projects in equipping students with indispensable skills and tools for developing prototypes of embedded systems, the authors introduced a novel approach to bridge industry-academia gap. The objective of this activity was to bridge the gap between academic learning and industry needs by fostering collaboration between educational institutions and local industries in the field of microcontroller development and application (Wu, 2020).

Through the active involvement in these practical projects, students not only apply theoretical concepts learned during lectures and labs but also cultivate valuable skills for their future careers. Accordingly a detailed draft to carry out the activity was meticulously planned as follows:

- Microcontroller-based local industries were identified and a survey was conducted to understand their specific needs and challenges.
- The skills and knowledge gaps between what students learn in academic programs and what industries required was assessed.
- Field visits to industries and guest lectures from industry representatives for students were organized to understand real-world applications.
- Approximately 65 real world problem statements were identified and finalized.
- Sixty teams were formed and each team was assigned a problem statement to work on.
- The activity was closely monitored through regular progress meetings, mentorship and guidance, feedback mechanisms,
- Resource allocation, project revisions, peer learning, industry feedback was also incorporated.
- Phase wise rubrics based assessment was carried out.

By following this plan, we have strengthened the course on microcontroller and provided students with practical skills and industry exposure, while local industries benefit from a skilled workforce and innovative solutions to real-world challenges.

C. Implementation

Fig. 2 illustrates the progressive stages of the strategy employed to cultivate advanced cognitive skills.

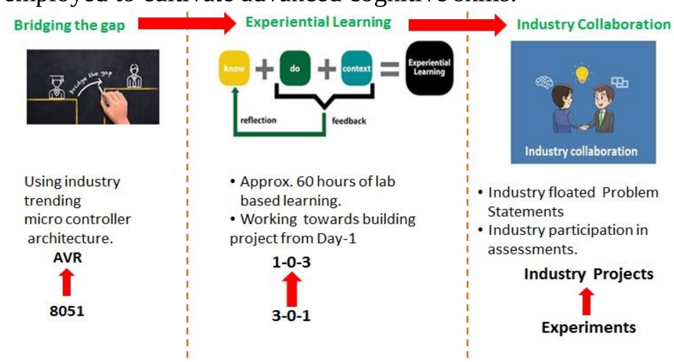


Fig.2.: Higher cognitive skill development in students

In Stage 1 (Bridging the gap), the course instructors engaged in dynamic brainstorming sessions to integrate an industry-relevant microcontroller, specifically the Atmega32, into the curriculum. The Atmega32 microcontroller was chosen over the 8051 for the microcontroller syllabus due to its widespread use, feature-rich architecture and relevance in industries like robotics, automation, consumer electronics, and IoT. (Yusof et al, 2020). This choice aims to prepare students for careers in these sectors, providing them with essential skills and a strong foundation in embedded systems. This proactive decision aimed to bridge the gap between theoretical learning and practical application. In Stage 2 (Experiential Learning), a cyclic process unfolded, wherein students embraced an experiential learning approach, delving deeper into the core concepts. This hands-on engagement empowered them to not only comprehend the subject matter but also to forge meaningful connections between theory and practice. Finally, in the Stage 3(Industry collaboration), a comprehensive assessment strategy was implemented, bolstered by industry collaboration. This collaboration enriched the evaluation process, ensuring alignment with real-world demands and validating the acquired cognitive skills within an industrial context. This holistic journey encapsulates the deliberate effort to nurture higher-order cognitive abilities in students, equipping them with the prowess to excel in practical scenarios. One of the pivotal enhancements to the course was the incorporation of a related laboratory component. This laboratory experience is instrumental in training students to adeptly utilize integrated development environments (IDEs) for crafting application programs in assembly and C languages. Moreover, the lab sessions facilitate hands-on engagement with hardware programming and the practical utilization of microcontrollers. Consequently, students are empowered to design prototypes of embedded systems, bridging the gap between theory and practice.

D. Assessment

Assessment was carried out for each module to assess various skills as shown in Fig. 3

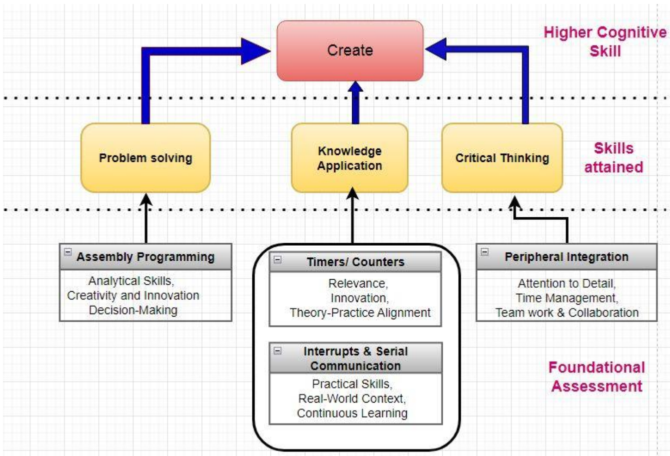


Fig.3.: Assessment Strategy

By engaging in the process of developing applications based on the knowledge gained from the course, students achieved higher-level cognitive skills that go beyond mere memorization or basic understanding (Kaczkó & Ostendorf, 2023).

Fig.4 shows one of the models exhibited by a student team

Fig. 4.: Model of student project exhibited

during their assessment, which was also appreciated by industry mentors. In general students were able to apply concepts in innovative ways, analyze complex problems, synthesize information, and evaluate various solutions. This practical application demanded critical thinking, problem-solving, and decision-making skills, as they had to navigate challenges, optimize code, and troubleshoot issues. Additionally, working on projects in teams enhanced their collaboration and communication abilities. They needed to communicate ideas clearly within their group, share responsibilities, and coordinate efforts to achieve common objectives. This interactive and collaborative aspect of application development contributes to their interpersonal and teamwork skills.

VI. RESULTS & DISCUSSIONS

This activity was strategically designed to elevate the cognitive skills of second-year undergraduate Computer Science students. It underwent a meticulous evaluation process, independently conducted by both course instructors and industry mentors. Each assessment was carefully aligned with specific rubrics, targeting distinct skills, and the resulting insights were diligently documented. Fig. 5 vividly illustrates the assessments performed by course instructors, focusing on essential skills encompassing problem-solving (Maries& Singh, 2023), knowledge application, and critical thinking (Giannakopoulos, & Buckley,2009). The synergy of these skills culminated in fostering creative thinking (Shehab & Nussbaum, 2015). Remarkably, the depicted results post-activity exhibits a noteworthy enhancement when juxtaposed with the pre-activity phase

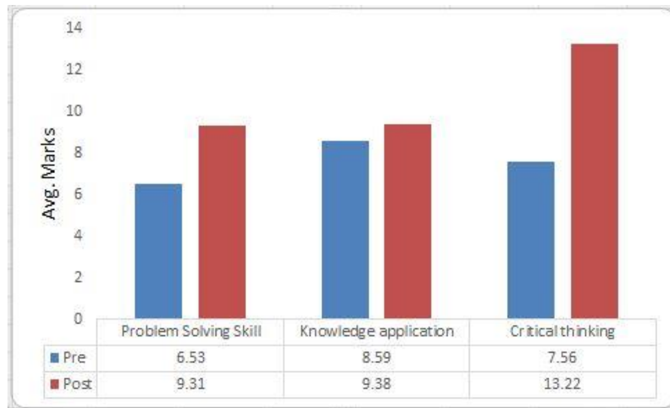


Fig.5.: Skill Attainment-Faculty Assessment

While the industry mentors provided close guidance and mentoring to the students throughout the activity, the assessment phase was deferred until after the activity concluded. Fig. 6 provides a visual representation of the outcomes, demonstrating that a substantial majority of students successfully met the industry's expectations in terms of problem-solving skills

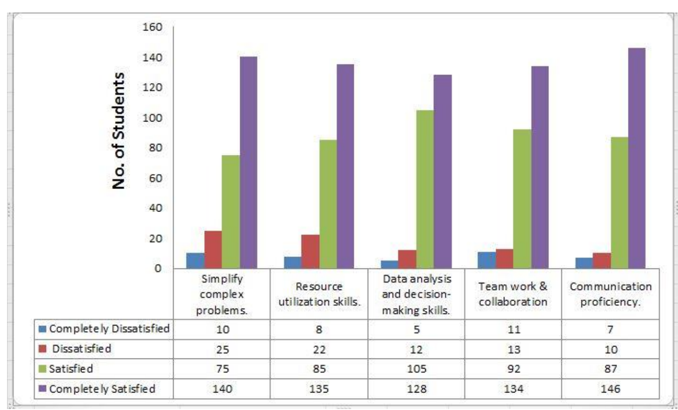
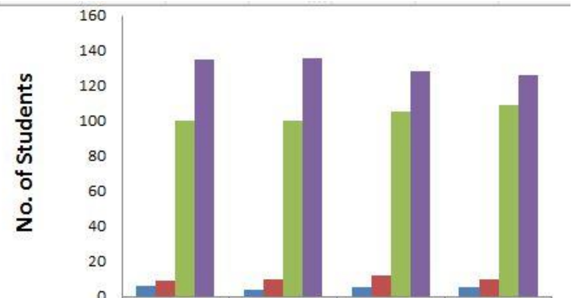


Fig.6.: Problem Solving Skill-Industry Assessment

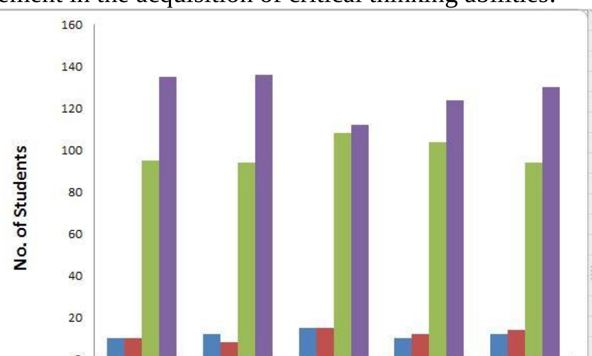
Students were required to apply the concepts they had grasped during their regular theory classes in the context of this activity. The degree to which they achieved this was also evaluated by industry mentors, and the results are visualized in Fig 7. This representation highlights a noteworthy enhancement in their application of these concepts, which left the mentors highly satisfied.



	Apply coursework knowledge to industry challenges	Alignment of student knowledge applications with industry standards.	Apply theoretical knowledge to meet industry needs.	Efficiently convey applied knowledge to industry stakeholders.
Completely Dissatisfied	6	4	5	5
Dissatisfied	9	10	12	10
Satisfied	100	100	105	109
Completely Satisfied	135	136	128	126

Fig.7: Knowledge Application Skill-Industry Assessment

The course instructors early on identified the significance of nurturing critical thinking skills in students. As a result, the conducted activity was meticulously aligned with assessing and enhancing these skills, an evaluation entrusted to the industry professionals. Fig. 8 visually portrays a substantial advancement in the acquisition of critical thinking abilities.



	Identify functional & non-functional requirements	Analyse the given problem	Evaluate options, considering data and pros/cons.	Address industry-related complex issues.	Propose innovative solutions to current issues.
Completely Dissatisfied	10	12	15	10	12
Dissatisfied	10	8	15	12	14
Satisfied	95	94	108	104	94
Completely Satisfied	135	136	112	124	130

Fig.8: Critical Thinking Skill-Industry Assessment

The results and discussions highlight the successful alignment of the course activity with industry expectations and the substantial improvements in higher cognitive skills achieved by the students (Kaczkó & Ostendorf, 2023. These findings underscore the practical relevance and effectiveness of the educational approach employed in this microcontroller activity.

VII. CONCLUSION

In essence, the practical application of knowledge through developing applications elevated students' cognitive abilities to higher levels, empowering them with skills and competencies that are not only valuable within the scope of microcontroller programming but also transferable to various contexts within the broader field of technology and engineering. In summation, this paper elucidates the authors' comprehensive strategy for rendering the Atmega32 microcontroller hardware course compelling and congruous with the academic pursuits of Computer Science undergraduates. The infusion of lab sessions and course projects serves to elevate the quality of learning, foster engagement, and aptly prepare students for further exploration into the domain of embedded systems

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