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ENHANCING TECHNICAL AND INTERPERSONAL SKILLS IN ENGINEERING EDUCATION THROUGH AUDIENCE RESPONSE SYSTEM (ARS) IN PROJECT-BASED LEARNING (PBL)

FARHAT Mohamad Hussein[1]
Department of Electrical and Electronics Engineering, College of Engineering, Australian University, Safat 13015, West Mishref, Kuwait.
***Email**: m.farhat@au.edu.kw*

NAHAS Michel [2]
Department of Electrical and Electronics Engineering, College of Engineering, Australian University, Safat 13015, West Mishref, Kuwait.

GHAREEB Nader [3]
Department of Electrical and Electronics Engineering, College of Engineering, Australian University, Safat 13015, West Mishref, Kuwait.

MUNISAMI Kevin [4]
Department of Electrical, Electronic and Robotic Engineering, Kingston University, UK.

ABSTRACT

In modern engineering education, addressing the diverse needs of students requires innovative teaching strategies that promote active learning and engagement. The integration of multimodal technologies, such as the Audience Response System (ARS), has emerged as a key tool for fostering interactive and personalized learning experiences. This study investigates the effectiveness of ARS in enhancing Project-Based Learning (PBL) within Electrical and Mechanical Engineering courses at the Australian University-Kuwait, focusing on its impact on technical skills, interpersonal communication, and teamwork. It's implemented during key stages of the project lifecycle, including project planning, progress reports, and final presentations. By providing real-time feedback, the system encouraged active participation and facilitated classroom discussions. Data were collected through instructor feedback and an anonymous student survey. The survey, which was later validated by the QM department at AU, was designed to evaluate student satisfaction and the overall impact of ARS on learning outcomes. Results revealed that students were highly satisfied with ARS, reporting significant improvements in both technical and interpersonal skills. it was concluded that ARS can facilitate active participation and diverse perspectives in classroom discussions, making students feel more comfortable by asking questions and engaging in collaborative learning. Instructors also noticed that ARS enhanced the overall learning experience by providing real-time feedback and fostering a more interactive classroom environment.The findings highlight ARS as a transformative tool for enhancing PBL in engineering education, improving both learning outcomes and student engagement. This study underscores the value of ARS in promoting active learning, collaboration, and skill development, preparing students for the challenges of their future careers.

1. Introduction:

In recent years, engineering education has increasingly shifted its focus from solely developing technical expertise to fostering critical interpersonal and soft skills. This evolution aligns with the global trend toward student-centered learning, which emphasizes active student participation in the educational process. As a result, traditional lecture-based teaching methods are being replaced by more interactive, collaborative, and practical approaches. These methods not only engage students more effectively, but also promote deeper learning and better preparation for real-world challenges. This shift is particularly relevant in the context of globalization, which has transformed the way individuals and organizations operate. Globalization, characterized by the growing interconnectedness and communication among individuals and nations, has brought profound social, educational, economic, and technological changes. In today's business environment, employers increasingly seek candidates with strong generic skills, particularly in communication and collaboration. These competencies have become indispensable for career success and are equally valuable in personal life. Effective communication and the ability to work collaboratively are now critical to achieving organizational goals, making these skills essential for enhancing employability and workplace effectiveness [1], [2], [3].
To be successful in the global marketplace, employers seek engineering graduates who possess not only disciplinary knowledge and technical skills but also the ability to communicate effectively and appropriately in diverse teams, adapt quickly to new environments, and consider the cultural contexts of engineering solutions [4], [5], [6].

At many universities, however, engineering programs, faculty, and students still focus almost exclusively on developing technical skills despite decades of scholarship and ABET accreditation standards that emphasise the need to hone non-technical skills required for well-rounded, 21st-century engineers [7], [8], [9], [10], [11].

Above all, engineering students consistently struggle with communication and teamwork, in large measure, due to curricular constraints and a lack of faculty expertise in how to effectively infuse non-technical skills development into undergraduate courses[12], [13]. Consequently, employers frequently invest resources into "training programs for new hires to augment engineering education with a broader set of skills". The skills gap negatively impacts graduates' ability to function in the global workplace, where communication in diverse teams is critical to success.

In response to the evolving educational landscape, higher education institutions and authorities have prioritized the development of programs focused on essential competencies. These competencies—an integrated set of skills, abilities, attitudes, and values—are critical for achieving personal and professional excellence [14], [15], [16], [17]. However, cultivating such competencies requires a paradigm shift in educational models. Institutions must move away from traditional, teacher-centered approaches, where the instructor serves as the primary source of knowledge, and instead adopt active, experiential learning methods. This shift enables learners to engage more deeply with the material and apply their knowledge to real-world situations, fostering collaboration, critical thinking, and problem-solving skills. Ultimately, this transformation aims to produce a better workforce equipped to address the dynamic challenges of a rapidly evolving global market. Research has shown that Project-Based Learning (PBL) is particularly effective in this regard, as its dynamic nature enhances communication and teamwork skills [18], [19], [20], [21].
PBL has emerged as a powerful pedagogical approach, especially in engineering disciplines. This hands-on approach encourages students to work in teams to design, prototype, and present solutions to real-world problems. Moreover, it bridges the gap between theoretical knowledge and practical application, allowing students to develop not only technical expertise but also essential soft skills such as teamwork, communication, problem-solving, and critical thinking. As engineering challenges grow increasingly complex, the need for such comprehensive skill sets has become vital for students' academic success and professional readiness.
The rapidly expanding knowledge base in different subjects necessitated the presence of a way to deal with the enormous amount of knowledge. Project-based Learning (PBL) effectively shifted emphasis away from collecting and absorbing knowledge to enabling students to learn effectively and independently[19], [20]. PBL is a student-centered educational method that aims to build problem-solving skills through self-learning and promote sustainable learning and teamwork skills. In the PBL process, learning is initiated by and structured around complex problems rooted in situations that the learner is likely to encounter in the real world outside of school [22]. It is a modern learning strategy that first originated in the 1950s at the medical school at Case Western Reserve University. Then, in the 1960s, McMaster University in Canada introduced it. It was initially introduced as a method of educating physicians to apply their knowledge in the perspective of real patient health problems [23], [24].
Project-Based Learning (PBL) offers significant benefits by fostering hands-on experience, collaboration, and real-world problem-solving. However, in additional to assessment challenges [19], PBL faces notable challenges, particularly in heterogeneous classrooms where students have diverse academic backgrounds, skill levels, and

learning preferences. Ensuring equitable participation, consistent engagement, and effective assessment in such environments can be difficult, as traditional methods often fail to address the varying needs of students. These challenges are especially pronounced in engineering education, where the development of both technical expertise and interpersonal skills is critical for student success.
Audience Response Systems (ARS) present a potential solution by enabling real-time, anonymous interactions that promote active participation, provide immediate feedback, and foster inclusivity. While ARS has proven effective in traditional lecture settings, its integration into PBL contexts particularly in engineering education has not been extensively studied. This lack of research represents a significant gap in the literature, as the dynamic and collaborative nature of PBL may uniquely benefit from ARS's interactive capabilities.
This study addresses this gap by investigating the integration of ARS into PBL courses within Electrical and Mechanical Engineering programs at the Australian University-Kuwait. It examines ARS's impact on students' technical and interpersonal skills, as well as their overall engagement and satisfaction, to provide insights into its potential for enhancing PBL outcomes.

Audience Response System (ARS)

Audience Response System (ARS) is also known as a personal response system [25], electronic voting system [26], student response system [27], and clickers [28]. These systems permit students to respond to different types of questions in different ways and by using different tools. One of the main advantages of ARS is in the fact that its instructional technologies allow instructors to collect rapidly and investigate student responses to questions posed during class. Typically, students are presented with multiple-choice, short-answer, or calculation questions. They respond by using an electronic device such as a mobile phone, tablet, or computer.

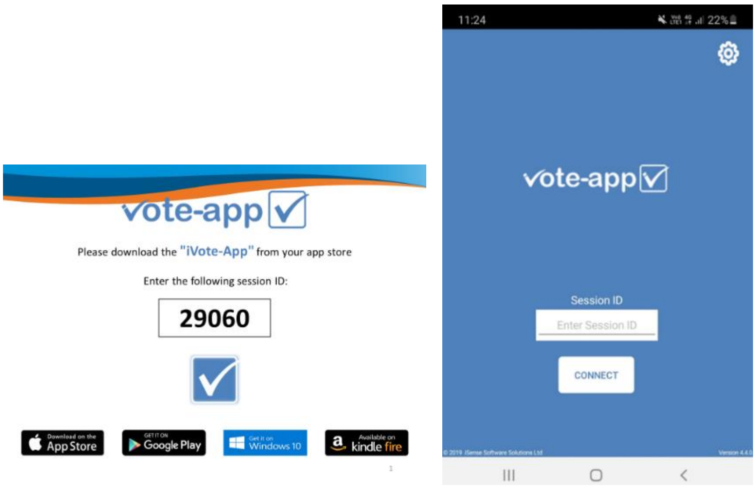
Research studies have found that the ARS or “clickers” provide significant educational benefits in higher education, such as classroom and learning benefits[29], [30] . Classroom benefits may include improved student attendance, engagement, motivation, and satisfaction. While student satisfaction is not necessarily an indicator of engagement or learning, students who enjoy learning will likely be engaged with the teaching and learn more.

Learning benefits may include improved student interaction, discussion, learning performance, and quality of learning [31], [32]. Assessment benefits may include improved student feedback and both formative and comparative learning assessment [33]. According to [34], clickers “typically have a caring or positive effect on student performance” and often “create a more positive and active atmosphere” in the classroom.

After students click on their responses, the results are instantly aggregated and displayed in chart form for the entire class to review. Responses are often anonymous, but the instructor can still assign an ARS remote device to specific students for evaluation purposes. Once the feedback is displayed, the instructor can change the course of instruction accordingly, or students can work out misconceptions and difficulties through peer or classroom discussions. While the use of ARSs started in 1966, only few papers could be found examining the use of ARS in engineering school classrooms [19], [35], [36], [37], [38]. However, the potential of implementing the ARS in PBL courses was not deeply investigated.

Methodology

This study investigates the use of ARS to enhance the learning experience in PBL courses offered by an Australian University-Kuwait. The study focused on three PBL courses: Microelectronic Design and Embedded Operating System from the Electrical and Electronics Engineering department, and Engineering Design and Management Implementation from the Mechanical Engineering Department. The objective is to explore how ARS could improve students' technical skills (e.g., theoretical analysis, software competence, and engineering design principles) and soft skills (e.g., critical thinking, communication, and teamwork), while boosting engagement and participation as well. At the beginning of the class, the instructor shares the session ID along with the instructions page with students that allows them to respond to the posted questions Figure 1.



(a) (b)

Figure 1. (a) ARS instruction page includes session ID. (b) student view

Students respond to the questions by entering the session ID in the pre-installed application on their devices. Once a question is posted by the instructors the students are notified to answer the question. After a predefined time, the students' responses (without their names) are posted on the board and the students got feedback on their devices.

The study involved undergraduate students who are enrolled in the three PBL courses, with a typical class size of 20 students. Students were divided into groups of four to five individuals to collaborate on a specific project as illustrated in Figure 2. The participants included students from diverse academic backgrounds and skill levels, reflecting the heterogeneous nature of the classrooms.

ARS was integrated into key stages of the project lifecycle to foster active participation, provide real-time feedback, and create an inclusive learning environment. In addition, ARS was used to prepare students for their assessments and submissions, ensuring they were well-equipped to meet the course requirements. All classes were following the operational flowchart as depicted in Figure 3. Below is an overview of how ARS was implemented:

1. Project Planning Preparation (Week 1)
   In the first week of the course, students were introduced to the project requirements and began developing their project plans. ARS was used during preparatory sessions to help students understand the key components of a successful project plan, such as scope definition, resource allocation, and risk management. Instructors posed questions via ARS to gauge students' understanding of these concepts and provide immediate feedback, ensuring they were well-prepared to create their project plans.
2. Progress Report Preparation (Mid-Semester)
   At the midpoint of the semester, students were required to submit a progress report and deliver a presentation updating the class on their project's status. ARS was used in preparatory sessions to help students organize their progress reports and practice their presentation skills. For example, students answered questions about structuring reports, presenting technical data, and addressing potential challenges. This allowed them to refine their work and build confidence before the actual submission and presentation.
3. Technical Sessions (Throughout the Semester)
   ARS was also used in technical sessions tailored to the specific requirements of each course. These sessions focused on deepening students' technical knowledge and skills, such as:
   - Microelectronic Design: Introduction to Microelectronics, Analog Circuit Design, SPICE Simulation and Testing and Validation.
   - Embedded Operating System: Introduction to Embedded Systems, Real-Time Operating Systems, Embedded System Architectures, Debugging and Testing Embedded Systems.
   - Engineering Design and Management Implementation: Introduction to Engineering Design, Design Thinking, Systems Engineering, Quality Assurance and Control, Sustainability in Engineering and Regulatory and Compliance Issues.

These sessions allowed students to revise their technical knowledge in real-time, receive immediate feedback, and clarify complex concepts, preparing them for the technical demands of their projects.

4. Final Report and Presentation Preparation (End of Semester)
   As the semester drew to a close, students prepared their final reports and presentations. ARS was used in preparatory sessions to help students organize their final deliverables and practice their presentation skills. Instructors posed questions about summarizing project outcomes, justifying design choices, and reflecting on lessons learned. This allowed students to refine their final submissions and presentations, ensuring they were well-prepared for assessment.

Throughout these sessions, students answered questions live and anonymously, ensuring that all participants could contribute without fear of judgment. The real-time feedback provided by ARS allowed instructors to adjust the pace and focus of the discussion based on students' level of understanding, creating a more dynamic and responsive learning environment.

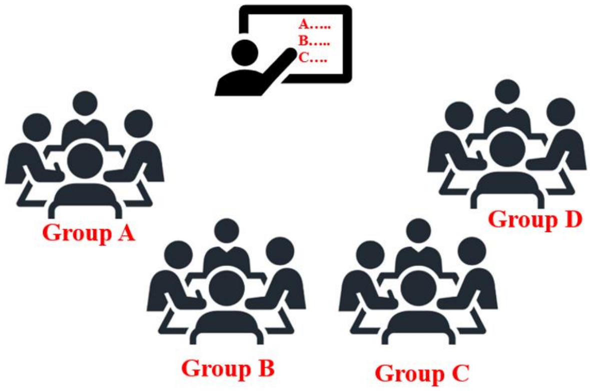


Figure 2: General PBL class

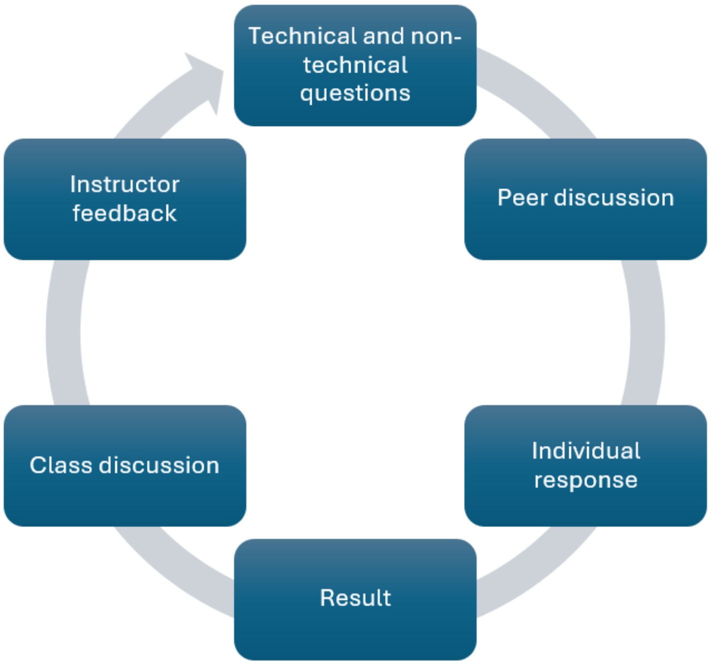


Figure 3. The response sequence for most ARS questions

Survey Design, Key Findings, and Results

To evaluate the effectiveness of the Audience Response System (ARS) in enhancing Project-Based Learning (PBL), data were collected through a combination of instructor feedback and student surveys. Several meetings were conducted with the involved instructors to gather their experiences and insights on the most effective methods of using ARS in the classroom. Students were also invited to contribute by completing an anonymous survey designed to assess their satisfaction with the new teaching style and evaluate various elements that contributed to active

learning. The survey was created using Microsoft Forms to simplify data collection and ensure accessibility. It was also validated by the QM department at the Australian University-Kuwait.
The survey objectives were clearly summarized and communicated to students before their participation. Students were informed that the survey was anonymous, voluntary, and not part of any assessment. They were also assured that all collected data were non-identifiable, it did not include any personal or sensitive information, and that their privacy and confidentiality were protected. Additionally, students were notified that once the survey was submitted, they could not withdraw their responses.
The survey was structured around five key hypotheses, each addressing a specific aspect of ARS effectiveness in PBL courses. These hypotheses focused on:

1. Student satisfaction with ARS.
2. Improvement in interpersonal skills (e.g., teamwork, communication, presentation skills).
3. Enhancement of technical skills (e.g., data analysis, software proficiency, engineering design).
4. Facilitation of classroom discussions and learning.
5. Overall engagement and participation.

Students responded to each question on a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). A total of 51 students participated in the survey, providing valuable insights into the impact of ARS on their learning experience.
The survey results as shown in table 1, revealed that:

1. High Satisfaction: Students were highly satisfied with ARS, with mean scores consistently above 4.0 and positive responses (Agree + Strongly Agree) exceeding 80% across all hypotheses. The highest satisfaction was reported for ARS being easy to use (mean = 4.82, 96.1% positive).
2. Improved Interpersonal Skills: ARS significantly enhanced students' teamwork, communication, and presentation skills, with 84.3% of students reporting improved confidence in presentations and 82.4% noting better teamwork.
3. Enhanced Technical Skills: ARS helped students better understand technical concepts and apply them in practical projects, with 84.3% reporting improved technical proficiency.
4. Facilitated Discussions: ARS encouraged active participation and diverse perspectives in classroom discussions, with 98.0% of students agreeing that it allowed for more inclusive discussions.
5. Increased Engagement: Students felt more comfortable asking questions and participating in discussions, with 84.3% expressing a preference for ARS-assisted discussions over traditional methods.

Table 1:

Hypothesis	**Key Finding**	**Mean Score**	**Positive Responses (%)**
Hypothesis 1:	Students were highly satisfied with ARS, especially its ease of use.	4.16 - 4.82	88.2% - 96.1%
Hypothesis 2:	ARS improved teamwork, communication, and presentation skills.	4.12 - 4.27	82.4% - 84.3%
Hypothesis 3:	ARS enhanced understanding of technical concepts and project planning.	3.96 - 4.43	68.6% - 82.4%
Hypothesis 4:	ARS improved technical knowledge and problem-solving abilities.	4.00 - 4.29	84.3%
Hypothesis 5:	ARS facilitated active participation, diverse perspectives, and engagement.	4.20 - 4.29	84.3% - 98.0%

The findings demonstrate that ARS is a powerful tool for enhancing PBL in engineering education. By fostering active participation, providing real-time feedback, and encouraging collaboration, ARS not only improves learning outcomes but also prepares students for the challenges of their future careers. The survey results support the broader adoption of ARS in PBL environments to enhance both technical and interpersonal skills.

Discussion

The results of this study demonstrate that the Audience Response System (ARS) is a highly effective tool for enhancing project-based learning (PBL) in engineering education. By integrating ARS into PBL courses, we observed significant improvements in students' technical skills, interpersonal skills, and overall engagement and satisfaction. Below, the key findings are interpreted, their implications are discussed, and recommendations for future practice are provided.

High Student Satisfaction with ARS

Students were highly satisfied with the use of ARS in PBL courses, with mean scores consistently above 4.0 and positive responses (Agree + Strongly Agree) exceeding 80% across all hypotheses. The highest satisfaction was with ARS being easy to use (mean = 4.82, 96.1% positive), indicating that the tool was accessible and user-friendly. The positive feedback suggests that ARS successfully addressed challenges such as maintaining engagement and ensuring equitable participation, particularly through its anonymous response feature, which encouraged participation from all students.

Improvement in Interpersonal Skills

ARS significantly enhanced students' interpersonal skills, such as communication, teamwork, and presentation skills. For example, 84.3% of students reported improved confidence in presentations, while 82.4% noted better teamwork. These results highlight ARS's potential to support the development of essential soft skills, which are increasingly valued in the engineering profession. By facilitating group discussions and presentations, ARS allowed students to practice articulating their ideas, receiving feedback, and collaborating with peers, aligning with the principles of active learning (Freeman et al., 2014).

Enhancement of Technical Skills

The survey results also indicated that ARS improved students' technical skills, such as coding, software proficiency, and engineering design principles. For example, 84.3% of students reported improved technical proficiency with many noting that ARS helped them better understand complex concepts through real-time feedback and discussions. This finding is particularly significant in engineering educationwhere technical competence is a core learning outcome. ARS enabled students to apply theoretical knowledge to practical problems, bridging the gap between theory and practice, a key goal of PBL.

Facilitation of Classroom Discussions and Engagement

One of the most notable findings was the impact of ARS on classroom discussions and engagement. A remarkable 98.0% of students agreed that ARS allowed for more inclusive discussions, while 84.3% expressed a preference for ARS-assisted discussions over traditional methods. The anonymity of ARS responses played a key role in encouraging participation, particularly among students who might otherwise hesitate to contribute. This highlights ARS's potential to address the challenges of heterogeneous classrooms, where students have varying levels of prior knowledge and confidence.

Implications for Engineering Education

The findings of this study have several important implications for engineering education. First, they demonstrate that ARS can be a valuable tool for enhancing PBL by fostering engagement, improving technical and interpersonal skills, and increasing student satisfaction. Second, they highlight the importance of integrating technology into the curriculum to support active learning and inclusivity. For educators, these findings suggest that ARS can complement traditional teaching methods, providing a more interactive and responsive learning experience. For institutions, they underscore the need to invest in technology-enhanced learning tools and provide training for faculty on their effective use.

Conclusion

This study investigated the use of the Audience Response System (ARS) in project-based learning (PBL) courses within electrical and mechanical engineering programs at the Australian University-Kuwait. The findings demonstrate that ARS is a highly effective tool for enhancing student engagement, improving technical and interpersonal skills, and increasing overall satisfaction in PBL environments.

The survey results revealed that students were highly satisfied with ARS, with mean scores consistently above 4.0 and positive responses (Agree + Strongly Agree) exceeding 80% across all hypotheses. ARS was particularly praised for its ease of use (mean = 4.82, 96.1% positive) and its ability to foster an inclusive and interactive learning environment. Students reported significant improvements in interpersonal skills, such as communication, teamwork, and presentation skills, as well as technical skills, including coding, software proficiency, and engineering design principles. Additionally, ARS facilitated more engaging and inclusive classroom discussions, with 98.0% of students agreeing that it allowed for greater participation and diverse perspectives.

The success of ARS in this study highlights its potential to address some of the key challenges associated with PBL, such as maintaining consistent engagement, ensuring equitable participation, and providing timely feedback. By leveraging ARS, educators can create a more dynamic and responsive learning environment that supports the development of both technical and soft skills, which are essential for students' academic and professional success.

These findings have important implications for engineering education. They suggest that ARS can be a valuable complement to traditional teaching methods, particularly in PBL contexts, and underscore the need for institutions to invest in technology-enhanced learning tools. To maximize the benefits of ARS, we recommend broader adoption in PBL courses, faculty training on its effective use, and the inclusion of diverse question formats to cater to different learning styles. Future research should explore the long-term impact of ARS on student learning outcomes and its applicability in other disciplines.

In conclusion, this study demonstrates that ARS is a powerful tool for transforming the learning experience in engineering education. By fostering active learning, improving skill development, and increasing student satisfaction, ARS has the potential to better prepare students for the challenges of their future careers and contribute to the ongoing evolution of engineering education.

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