CULTIVATION OF PROFESSIONAL ELECTROACOUSTIC TALENT USING CDIO INNOVATIVE TEACHING METHODS

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ABSTRACT

The purpose of this study was to apply Conceive-Design-Implement-Operate (CDIO) innovative teaching methods combined with Project Based Learning (PBL) to the cultivation of talent with the professional and technical knowledge required by the electroacoustic industry. The study period was three years, with the first and second semesters of each academic year considered one research cycle. The research subjects were first-year students in Feng Chia University's Master's Program of Electro-acoustics. There were a total of 34 students during the three years, working in teams of 3-4 students each. Headsets served as the research subject. First, students became aware of the development of electroacoustic market trends and the history of headphone brands (Conceive). Then, they learned how to construct the geometry of the components using CAD and simulated the acoustic radiation characteristics of headphones with equivalent circuit model (ECM) (Design). Subsequently, they remade headphones using CAD and 3D printer (Implementation). Finally, they compared the sound pressure characteristics of the physical and simulated earphones and optimized the design (Operation and Optimization). Their learning effectiveness was analyzed using pre-test and post-test questionnaires and rubrics. Results showed that learning effectiveness increased significantly by 65.2% following the introduction of the proposed innovative teaching model. The most significant results were in the Operation and Optimization stages, reaching more than 70.2%. This indicated that learning processes combined with PBL and hands-on practice can effectively improve students' motivation to learn.

KEYWORDS

CDIO, Electroacoustics, Headphone, Questionnaire, Standard 5, Standard 6

INTRODUCTION

Human resources are important assets in this era of the knowledge economy and a key factor for industrial upgrades and enhanced competitiveness. Facing an increasingly competitive international market, any educator who is dedicated to improving the current education system must consider two issues: (1) The knowledge, abilities, and attitudes that students should possess when they graduate to be able to cope with the changing market, and the level of proficiency that they should achieve. (2) What educational institutions can do to ensure that graduates have the proper knowledge, abilities, and attitudes. These long-standing issues in engineering education also exist in the current cultivation of professional electroacoustic talent.

In recent years, one of the most successful and influential achievements in the international engineering education field has been the development of Conceive-Design-Implement-Operate (CDIO) innovative teaching methods, which have been promoted by Worldwide CDIO Initiative. In engineering education, these teaching methods have been inspired by the product development cycle, including process and system conception, design, implementation, and operation. Emphasis is placed on an integrated curriculum for students to master basic engineering theories and professional knowledge, through active and practical problem-solving, teamwork, and innovative practices, to acquire the capabilities required by engineers (Crawley et al., 2014).

Based on CDIO, Al-Atabi (2014) pointed out the themes and requirements for professional engineers at each stage of training. These are consistent with the training of electroacoustic professional technicians conducted by this institute. In 2017, Zarei et al. mentioned that engineering science education should include diversified learning resources to meet students' learning needs, while being adaptable to students' individual learning styles and speeds. The quality, accessibility, and acceptability of learning resources can be improved through appropriate design of mobile learning. Edström (2020) emphasized the importance of quality, suggesting that under the definition of a quality mechanism, work that is neither academic nor useful can be systematically eliminated and boundaries and standards can be defined.

Project Based Learning (PBL) is learner-centered and allows students to independently engage in design, problem solving, decision-making, research, and other related work to solve challenging problems (Jones et al. 1997, Thomas et al., 1999, Thomas, 2000). Edström and Kolmos (2014) have suggested that PBL and CDIO play compatible and complementary roles. Thus, they can be effectively combined to reform engineering education. In the assessment, Yajima et al. (2021) described that self-assessment, peer assessment, and teacher assessment after the PBL showed the improvement in the target skills. In a recent study, Boelt et al. (2022) further demonstrated the synthesis of generic competencies perceived by engineering students in a PBL environment and illustrated the landscape of generic competencies, providing a frame of reference for discussing strategies for developing the broad range of generic competencies required of future engineers as they address complex social challenges. Jun Suzuki et al. (2022) also verified the improvement of general skills (GSs) by using a cross-course-typed (integrated) PBL in one of Experimental subject 4th grade.

The Master's Program of Electro-acoustics, established at Feng Chia University (FCU) in 2007, is currently the only program that systematically cultivates electroacoustic professionals in Taiwan. It not only has a comprehensive teaching staff and software and hardware, but is also in line with domestic and foreign electroacoustic education in terms of teaching axes and curricula. The instructors are aware of current development needs of the industry, due to their close links to the domestic electroacoustic industry. Moreover, the curriculum is updated and redesigned every year in response to global electroacoustic trends. Before 2018, the foundation of this academic program was laid, while focusing on and continuously linking industrial needs and academic research, and accumulating technical energy and in-depth understanding of industrial needs. After 2018, it was recognized that the global electroacoustic industry and relevant technology were undergoing rapid development, leading to an exponential demand for high-level electroacoustic talent. Therefore, understanding how existing resources, such as time, manpower and material resources, can be utilized to integrate relevant technologies and courses and cultivate more capable, high-level, electroacoustic technical personnel is the main motivation of this study.

OBJECTIVE AND METHDOLOGY

Objective

Based on the needs of the industry and continuous feedback on the curriculum and content of educational programs, there are 4 existing problems related to the linkage between curriculum and talent training: (1) Insufficient and coherent teaching; (2) Lack of interdisciplinary technology integration; (3) Lack of themes and non-interactive learning atmosphere; (4) Lack of professional depth and reporting capabilities. Therefore, improving the relationship between teaching and learning effectiveness to meet the electroacoustic industry’s demand for technical talent is of major importance. In this study, a CDIO innovative teaching strategy was introduced and electroacoustic measurement methods were integrated with basic theory. Courses were the main teaching sites and PBL teaching method was selected, with headphone products as the target, to enable students entering this Master's degree program to systematically and completely absorb professional and technical knowledge, as shown in Figure 1.

Figure 1. Concepts for the cultivation of electroacoustic industry talent in this study.

Methodology

Teaching Site

Two professional courses, Fundamental Acoustics and Electroacoustic Measurement and Methods, taught by the author in the first and second semesters were the main teaching and research sites in this study. Other courses, such as Electroacoustic Electronics and Electroacoustic Transducer Design, served as supplements, in addition to the involvement of professionals from electroacoustic enterprises. It was expected that through the introduction of diverse design elements and themes that learning desire and motivation could be significantly strengthened. Furthermore, students made use of international electroacoustic laboratories (Anechoic Chamber) and relevant measurement equipment (SoundCheck and KLIPPEL system), as shown in Figure 2, for learning and verification.

Figure 2. International electroacoustic laboratories and relevant measurement equipment.

Research Objects

The research objects were mainly first-year students in the Master's Program of Electro-acoustics. A total of 9 teams were formed, each with 3-4 students. Over the 3-year study period, there were a total of 34 students, as shown in Figure.3. A few electroacoustic industry professionals also attended the classes.

Figure 3. Research objects during the 3-year study period.

Research Structure

With CDIO as the core and headphones the main target, each course was completed step by step, including the introduction of brand histories, classic headphone design concepts, CAD, simulation analysis, reverse engineering, and measurement verification, as shown in Figure 4.

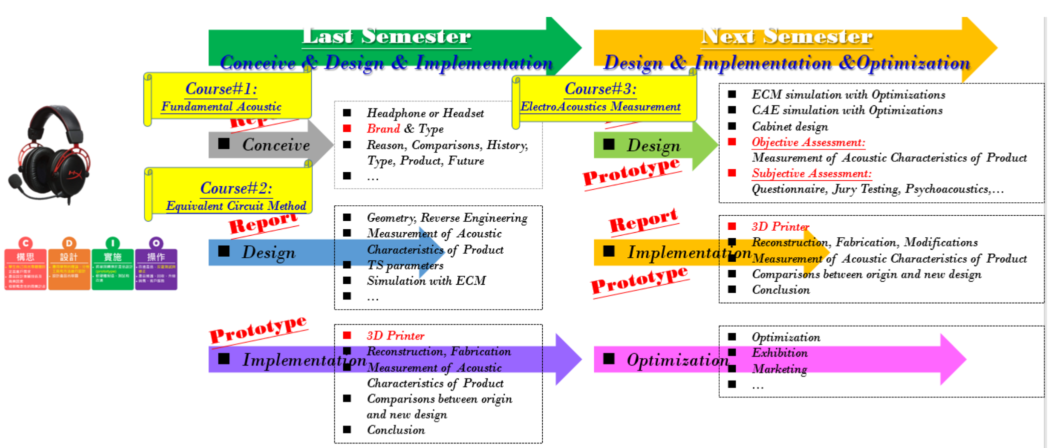
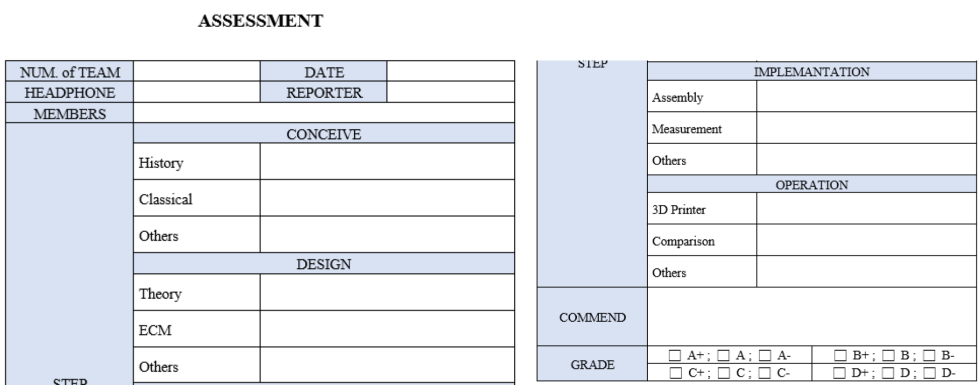


Figure 4. Research structure

Research Assessment

To understand the learning effectiveness of students who participated in this innovative teaching model, we collected written and oral mid-term and final reports, encouraged mutual assessments of teachers and peers, and developed pre-test and post-test questionnaire with Rubrics evaluation method. Figure 5 and Table 1 show the assessment form and questionnaire. The questionnaire was divided into four major sections, according to the CDIO structure, made up of questions 1-6, 7-15, 16-19, and 20-22, respectively. Questions 23 and 24 were used to understand the level of agreement of students on whether this innovative teaching model should be applied to future electroacoustic talent training.


ASSESSMENT

NUM. of TEAM		DATE	
HEADPHONE		REPORTER	
MEMBERS			
STEP	CONCEIVE		
	History		
	Classical		
	Others		
	DESIGN		
	Theory		
	ECM		
	Others		

STEP	IMPLEMANTATION	
	Assembly	
	Measurement	
	Others	
	OPERATION	
	3D Printer	
	Comparison	
	Others	
COMMEND		
GRADE	☐ A+ ; ☐ A ; ☐ A-	☐ B+ ; ☐ B ; ☐ B-
	☐ C+ ; ☐ C ; ☐ C-	☐ D+ ; ☐ D ; ☐ D-

Figure 5. Assessment form and questionnaire

Table 1. Questionnaire question at each stage

Steps	Questions
CONCEIVE (C)	1. I am familiar with the headphone brands on the market. 2. I have a favorite or familiar brand of headphones. 3. I know the history of headphone brands. 4. I understand the development of headphone brands. 5. I understand the characteristics of headphone brands. 6. I understand the monetary value of headphones on the market.
DESIGN (D)	7. I understand the components of a headphone unit. 8. I understand the components of a headphone system. 9. I understand that headphone cavities affect frequency response. 10. I understand that a headphone cavity opening affects the frequency response. 11. I understand what an equivalent circuit is. 12. I understand the theory of equivalent circuits. 13. I understand how equivalent circuits are used in headphone unit simulation. 14. I understand how equivalent circuits are used in headphone system simulation (considering monomers and cavities). 15. I understand the TS parameters required by the equivalent circuit to simulate the headphone unit.

IMPLEMENTATION (I)	16. I understand the measurement of acoustic characteristics of headphone units. 17. I can compile my own program for measuring the acoustic characteristics of headphones. 18. I can operate the headphone acoustic characteristics measurement program by myself. 19. I can interpret headphone acoustic characteristics measurement results.
OPERATION (OPTIMIZATION) (O)	20. I know about 3D printers. 21. I can operate a 3D printer by myself. 22. I can troubleshoot problems during the 3D printing process by myself.
OTHERS	23. I recommend that this topic continue to be used in electroacoustic training programs. 24. I like the course content and planning of this topic.

RESULTS AND DISCUSSION

This study was conducted over 3 years, 2018, 2019 and 2021, and focused on the cultivation of electroacoustic industry talent, especially in terms of the recognition, design, measurement, simulation, and remaking of electroacoustic products, such as headphones. During this period, a total of 9 headphone products including DENON-HP700, ATH-AR1, Cooler Master MH751, JVC HA-FW10000, AKG K815LE, KOSS Porta Pro, ATH-M50x, AKG-K52, and RAZER Black Shark V2 X were studied and remade. The price of these headphone products ranged from TWD $2,000-4,000 and the diameter from 40 mm-50 mm. In Figure 6 is presented a flow chart completed by one of the student teams for a specified headphone product. Each headphone product underwent acoustic characteristics testing, disassembly, component graphics drawing, simulation comparison, 3D printing, reassembly, and comparison verification.

Figure 6. Flow chart for the remaking of headphones in this study.

Remade Headphones

Figure. 7 shows that each group of students was able to successfully remake headphones. Almost all comparisons were good. In addition, first-year students were encouraged to participate in the International Electroacoustic Forum and present posters. Figure 8 shows the posters produced by each group of students according to year.

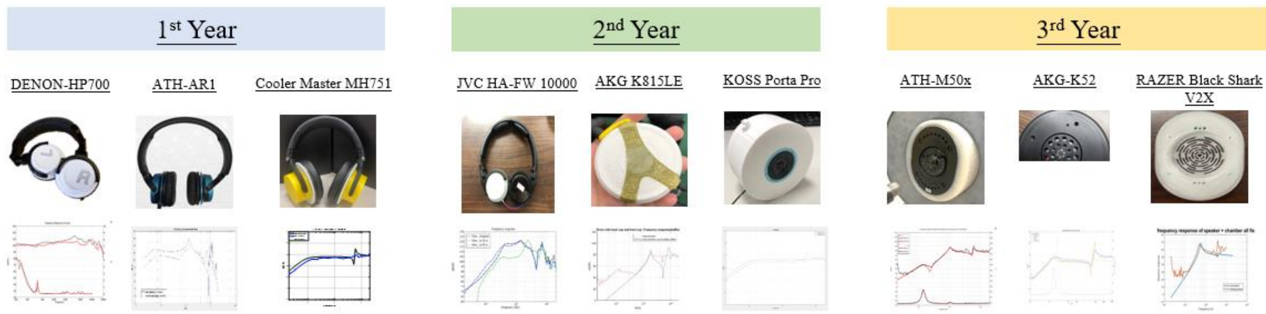


Figure 7. Results of the remade headphones and verifications between simulation and measurement.

Figure 8. Posters of the 3 teams in the first year (2019)

Learning Effectiveness

The statistical results for learning effectiveness each year and the averages of 3 years are summarized in Figure 9. The overall 3-year averages for the 4 sets of questions were between 1.05 and 1.26, among which Design and Operation stage scores were the lowest, 1.16 and 1.05, respectively. It is speculated that this is mainly because students had just entered the electroacoustics program and were still in the exploratory stage. Thus, most of their understanding of electroacoustics was based on what they had seen and heard in the past and personal preferences. However, most students had a considerable degree of motivation and desire to study electroacoustics based on the average score of 2.71 for questions 23 and 24.

At the end of the courses taught using CDIO and PBL methods, students' performance significantly improved. The overall average increased to 2.98~3.52, or more than 1.0 times when compared with the start of the class. From observations of student performance at each stage of CDIO, there were clear differences among the 4 learning stages of Conceive, Design, Implementation, and Operation, with averages of 57.9%, 67.3%, 65.4%, and 70.2%, respectively. The overall average growth was 65.2%. Among them, the best growth ratios were in the Operation and Design stages, respectively. The main reason is that in these stages students learned reverse engineering methods to complete the re-assembly of earphones and compare them with the original acoustic characteristic measurements. Since these processes required hands-on practice coupled with multiple adjustments and verifications by students, it was much easier to attract students' attention and improve their motivation and desire to learn.

From the analysis of the last two questions of the questionnaire, it was clear that students agreed that this innovative teaching model (CDIO with PBL) is of considerable help to those who are just entering the field of electroacoustics. Among the post-test results, the highest score of 5 points was given. Compared with the pre-test results, this was an improvement of around 2 times. In addition, students mentioned that due to the introduction of this creative teaching model, they not only developed a solid foundation in electroacoustic theory and technology, but also had the opportunity to learn about diverse electroacoustic technologies and find thesis topics. At the same time, people working in the electroacoustic company expressed that this model not only helps to cultivate electroacoustic professionals who meet the industry's demand for talent, but also effectively reduces the gap between learning and implementation.

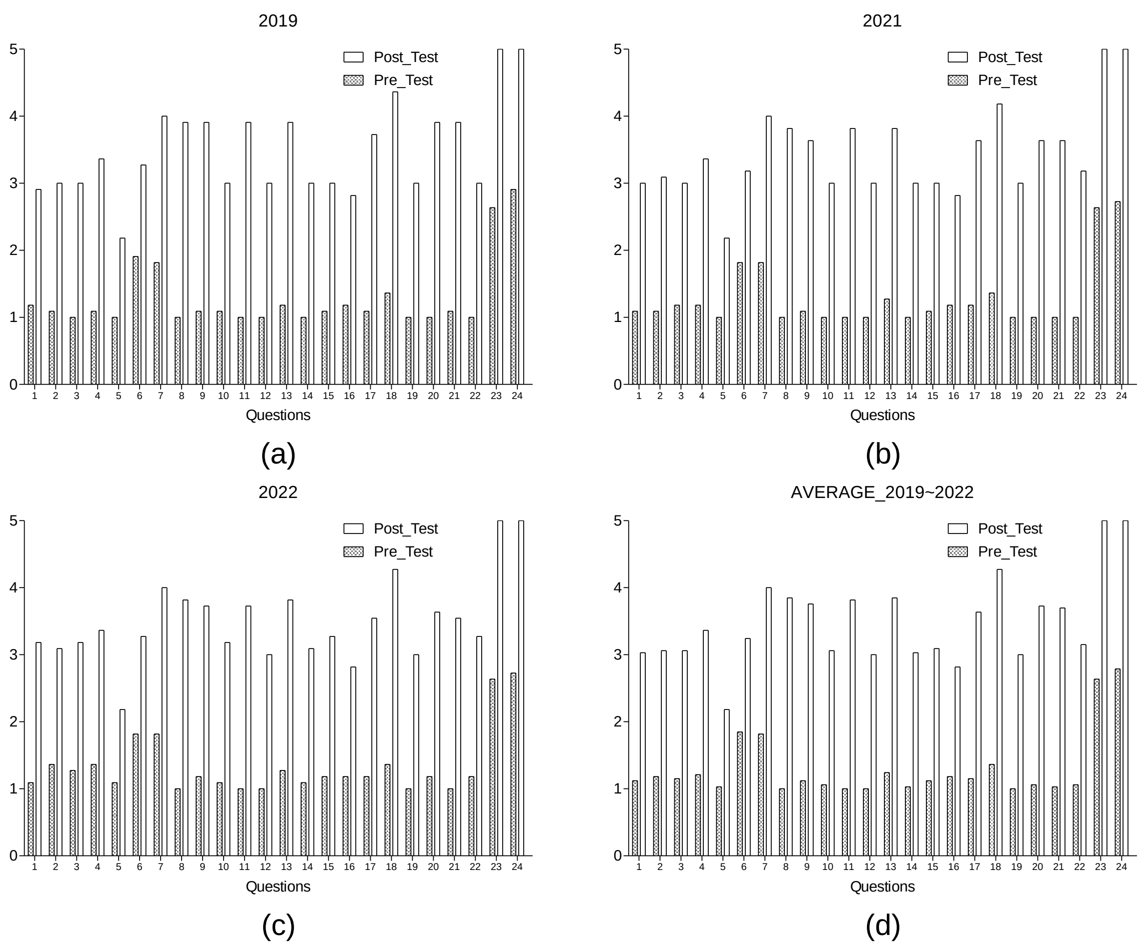


Figure 9. Statistical results of learning effectiveness of students; (a) each year; (b) average of 3 years

CONCLUSION

An innovative learning model of CDIO combined with PBL was proposed for the education of electroacoustic talent. The results showed that this model not only provides students with clear learning goals, but also systematically leads students in understanding electroacoustic industry trends, professional knowledge, theories, and technologies step by step, while simultaneously enhancing their motivation and desire to learn. This model also provides a solid foundation for a two-year Master's program and a clear vision for thesis topics. The students trained using this creative model have received positive reviews and praise from their employers in the electroacoustic industry following graduation.

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REFERENCES

Al-Atabi, M. (2014). Think Like an Engineer: Use systematic thinking to solve everyday challenges & unlock the inherent values in them. *CreateSpace Independent Publishing Platform*.

Ataollah Zarei, Khairiyah Mohd. Yusofa, Mohd Fadzil Dauda, Dayang Hjh. Tiawa Awang Hj. Hamidb, 2017, "*Mobile Learning for Engineering Education Reform*", SAINS HUMANIKA, Vol. 9, No. 1-2, pp.1-6.

A. M. Boelt, A. Kolmos, J. E. Holgaard (2022). Literature review of students' perceptions of generic competence development in problem-based learning in engineering education. *European Journal of Engineering Education. Vol. 47. p. 1399 - 1420*. https://doi.org/10.1080/03043797.2022.2074819

Crawley, E., Malmqvist, J., Ostlund, S., & Brodeur, D. (2014*). Rethinking engineering education: The CDIO Approach* (2nd ed). Springer Singapore: Springer.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). Real-life problem solving: *A collaborative approach to interdisciplinary learning. Washington, DC: American Psychological Association*.

Jun Suzuki, Koji Kawasaki, Kuniaki Yajima, Shinji Chiba, Hisashi Takeshima (2022). VISUALIZING THE EFFECTIVENESS OF CROSS-COURSE-TYPED PBL ON GENERIC SKILLS. *Proceedings of the 18th International CDIO Conference, hosted by Reykjavik University, Reykjavik Iceland, June 13-15,*

Kristina Edström & Anette Kolmos (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*. Vol. 39. p. 593-555. https://doi.org/10.1080/03043797.2014.895703

Kristina Edström (2020). The role of CDIO in engineering education research: Combining usefulness and scholarliness*. European Journal of Engineering Education*. Vol. 39. p. 113-127. https://doi.org/10.1080/03043797.2017.1401596

Thomas, J. W. (2000). A review of research of project-based learning. Retrieved from http://www.autodesk.com/foundation.

Thomas, J. W., Mergendoller, J. R., & Michaelson, A. (1999). Project-based learning: *A handbook for middle and high school teachers. Novato, CA*: The Buck Institute for Education.

Wolk, S. (1994). Project-based learning: pursuits with a purpose. *Educational Leadership*, 52(3), 42-45.

Yajima, K et al. (2020). A Report of Cross-course-typed Pbl And Students' Self-assessment, In *Proceedings of the 17th CDIO International Conference (CDIO2021),* 236-246.

BIOGRAPHICAL INFORMATION

Y.C. Liu is an associate professor who has been teaching in the Bachelor's Program of Precision System Design at Feng Chia University (FCU) since 2015. Currently, he is also an adjunct associate professor in the Master's Program of Electro-acoustics at FCU. He has been the main curriculum planner and instrumental in introducing innovative teaching methods. He earned his PhD in Mechanical and Aeronautical Engineering from FCU in 2008. His research interests include structural acoustics, electroacoustics, transducer design, numerical analysis, and finite element analysis (FEM). In charge of FCU's Electroacoustics Laboratory since 2009, he has familiarized himself with well-known electroacoustic measurement systems, such as Bruel & Kjaer, SoundCheck, KLIPPEL, and Audio Precision (AP), as well as LabVIEW system. Recently, he has applied FEM to investigate and optimize acoustic characteristics of microphones and speakers (loudspeakers and microspeakers), as well as to reduce noise produced by industrial machines. Additionally, he has carried out many industrial projects to solve noise issues and develop innovative solutions.

Shu-Chien Wu is a Ph.D. candidate who has been studying Ph.D. degree in the Ph.D. Program of Mechanical and Aeronautical Engineering at Feng Chia University (FCU) since 2019. Currently, she is also a Project manager at Electronic Acoustic Technology Development Society. She previously worked as an acoustic engineer at Meiloon Industry. Inc. from 2010 to 2014 and worked as a Special Assistant to CEO at Usher Audio company during 2015. She earned his master's degree in Master's Program of Electro-acoustics from FCU in 2010. Her research interests include electroacoustics, transducer design, Sensory Analysis, and statistics. During the doctoral program, she has familiarized himself with well-known electroacoustic measurement systems, such as Bruel & Kjaer, SoundCheck, KLIPPEL, as well as Audio Precision (AP). Recently, she has applied Sensory Analysis to investigate and explore acoustic characteristics of headphones. Additionally, she has carried out many industrial projects to solve Sound Quality issues.

Tzu-Hsuan Lei is a Ph.D. candidate who has been studying Ph.D. degree in the Ph.D. Program of Mechanical and Aeronautical Engineering at Feng Chia University (FCU) since 2020. He previously worked as an acoustic engineer at Fortune Grand Technology Inc. from 2017 to 2018 and worked as an acoustic engineer at Quanta Computer Inc. during 2019. He earned his master's degree in Master's Program of Electro-acoustics from FCU in 2017. His research interests include electroacoustics, transducer design, numerical analysis, and finite element analysis (FEM). During the course of the doctoral program, he has familiarized himself with well-known electroacoustic measurement systems, such as Bruel & Kjaer, SoundCheck, KLIPPEL, as well as Audio Precision (AP).Recently, he has applied FEM to investigate and optimize acoustic characteristics of microphones and speakers (loudspeakers and microspeakers). Additionally, he obtained invention patents in the Republic of China and the United States for the prediction method and system of porous material.

Tzu-Hsuan Lei is an Ph.D. Students who has been studying in the Ph.D. Program of Mechanical and Aeronautical Engineering at Feng Chia University (FCU) since 2021. He has been working at PAL Acoustics Technology from 2019 to 2021 as Quality Manager and Technical Manager. His research interests include structure, flow fields, structural acoustics and electroacoustics. Since 2019, he has been working with electroacoustic measurement systems such as Bruel & Kjaer, SoundCheck, KLIPPEL, and Audio Precision (AP), Head

Acoustics-ArtemiS SUITE, Head Acoustics-ACQUA. Recently he has applied finite element software to study the acoustic characteristics of loudspeakers and noise reduction in industrial products, as well as spatial sound measurement.

P.C.Ting have primarily worked as a professional sound system application engineer and engineering designer for performance sound system. I am in the process of studying for my Ph.D of Mechanical and Aeronautics Engineering degree at Feng Chia University in Taichung, Taiwan. My main research is focused on analyzing the coupling applications of electroacoustic products and venue acoustics. In addition, I have a strong interest in designing electro-acoustic products and using the knowledge and skills I learned in school, I've been involved in designing some products. My goat for the future is to both study theoretically and practice more to achieve better research results.

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