Perceived Benefits and Post-Programme Electrochemistry Attainment Following Collaborative Teaching in Foundation Chemistry II

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DOI: https://doi.org/10.47772/IJRISS.2026.100500159

Received: 01 May 2026; Accepted: 07 May 2026; Published: 25 May 2026

ABSTRACT

Electrochemistry is often considered as amongst the conceptually most challenging subjects in introductory chemistry since students are required to bridge the redox concepts, symbolic representations, particulate reasoning, and quantitative problem solving. This paper is a journal-like assessment of this collaborative teaching project, which seeks to reinforce the learning process of electrochemistry in CHM096 Foundation Chemistry II. The sources that were analysed are documentary, evaluative, and assessment related sources that are pertinent to implementation and effects of the programme. It was a lecture-based programme about redox reactions, galvanic cells and standard electrode potential in a cooperative learning session between course lecturers and a guest lecturer. The response of students was extremely positive: 87 responses were obtained, 86 of 87 students stated that they completed the session, the mean score rating was approximately 4.70 out of 5, and around 95.9% of all the ratings were 4 or 5. The most impressive dimensions were meeting programme goals, mastery of the speaker, good presentation, and clarity of explanation. Nonetheless, confidence in responding to electrochemistry questions, final-exam preparation, galvanic cells, and standard electrode potential, was found to have relatively lower ratings. Examining charting revealed that electrochemistry provided 20 marks to the CHM096 final paper, with most of the requirements being within the structured section. An analysis of 99 valid 2025 scripts revealed moderate but encouraging post-programme performance, the mean score in Question 4 was 4.41/8, in Question 5 was 3.48/8 and in electrochemistry structured score was 7.90/16 (49.4%). Notably, electrochemistry structured section performance was higher as compared to performance on the remainder of the structured questions in general. The results indicate that the collaborative teaching was positively accepted and linked to the promoting post-programme attainment of electrochemistry, and also indicated that galvanic-cell reasoning, standard electrode potential and examination-type problem solving requires further reinforcement.

Keywords: collaborative teaching, electrochemistry, foundation chemistry, student feedback, final examination

INTRODUCTION

It is common knowledge that electrochemistry can be considered as one of the most challenging subjects of introductory chemistry due to its expectation of coordination of redox, symbolic representations, reasoning in parts, and quantitative problem solving [1–6]. The previous studies on the topic of chemistry education have consistently revealed the following errors among the students in their understanding of a galvanic cell, an electrolytic cell, flow of electrons, salt bridge, standard potential of electrodes, and connection between oxidation-reduction reactions and equilibrium [1–7]. These barriers to learning are important in foundation chemistry since electrochemistry is not just a content area; also a conduit between conceptual knowledge and analytical problem solving of subsequent chemistry learning.

Collaborative and active teaching methods are now becoming established as important teaching practices in higher education due to their potential to enhance interaction, student success, and more substantive learning in stressful STEM environments [8–11]. In chemistry education, in particular, interactive teaching patterns can be particularly helpful where students need to be taught challenging threshold concepts that can be better explained in several ways, through guided practice, with particular focus given to common stereotypes [7,8,12]. Here, a collaborative teaching project was arranged in CHM096 Foundation Chemistry II to help students in the area of electrochemistry and redox reactions, galvanic cells, and standard electrode potential.

The current document is a report of an education-based evaluation of such an initiative based on institutional documentation and post-programme evaluation evidence. Instead of stating a definite effect of an experiment, the study investigates the consistency of the evidence of the available post-programme based on supporting a positive contribution of instruction to the learning of electrochemistry. Analysis will combine evidence of student assessment, course assessment materials, and cohort-level performance data to compare the perceived and actual results of the intervention.

LITERATURE REVIEW

Electrochemistry as a conceptually demanding chemistry topic

Chemistry education research continually highlights electrochemistry as a challenging topic because students need to draw together concepts related to oxidation-reduction, cell notation, reactions at electrodes, electron and ion movements, standard electrode potentials and calculations for cells [1,3–6]. Unlike other areas that can be learned primarily through direct observation or substitution of variables, the discipline of electrochemistry can involve translation among chemical equations, experimental cell notations, particulate-level explanations and basic thermodynamics. As a result, it is particularly difficult for first year students, who are learning to manipulate the types of representations and quantitative skills that they will use in subsequent chemistry courses [13–15].

The challenge of electrochemistry can be viewed in the context of broader chemical representation theory. Johnstone noted that chemistry is harder to learn when students have to simultaneously keep in mind the macroscopic, submicroscopic and symbolic levels [14,16]. Subsequent reviews and revisitations of the chemistry triplet stress the importance of not only identifying these levels, but also of making useful translations between them in chemistry learning [17–20]. This is evident from electrochemistry. Students could see a cell, write a half-equation, label an anode and cathode, calculate E_{cell}, and predict spontaneity, but each of these tasks may involve a different level of representation. A student who memorises how to do each of the exercises, but fails to connect the levels, may still struggle to complete the examination item when it is presented in a different diagram or number.

Students' misconceptions and learning barriers in electrochemistry

Electrochemical misconceptions have been reported for decades. Initial studies indicated students commonly misconceive roles of the salt bridge, electrolyte and electrodes in galvanic cells and electrolytic cells, and possibly have misconceptions regarding current in the electrolyte solution [1,5]. Other research showed students' continuing difficulties with half-cell potential, cell potential, electrochemical equilibrium, the role of the standard hydrogen electrode (SHE) and the connection between redox reactions and electrical work [3,7]. This is not an isolated issue. Studies comparing Indonesian and Japanese students found electrochemical concepts are difficult no matter the context, especially when students' understanding is assessed through interpretation of representations, rather than definition-memorisation [4].

There are a number of specific difficulties relating to the CHM096 emphasis on oxidation, galvanic cells and standard potential. First, students have difficulty with oxidation and reduction when these terms are isolated from electron movement and/or half-equations are set within unfamiliar species [1,2,5]. Second, learners may identify the anode and cathode incorrectly, based on position in the diagram as opposed to the oxidation or reduction reaction occurring [3,7]. Third, interpretation of standard reduction signs and values is difficult for many students because the magnitude and sign of E_{red} values must be linked to direction of electron transfer, strength of oxidising and reducing agents, prediction of spontaneous reactions [3,4]. Fourth, electrolysis introduces another

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue V May 2026

conceptual challenge due to the application of external electrical energy to drive a non-spontaneous reaction, which may contradict generalisations made about galvanic cells [1,4,5].

Explanations in textbooks and instruction can also be confusing if they rapidly introduce electrochemical conventions [1,5]. Sanger and Greenbowe found that chemistry textbooks can be sources of misconceptions when the explanations of current, electron flow, salt bridges and cell notations are ambiguous and disjointed [6]. This is particularly relevant to teaching foundation chemistry content where students may be presented with extensive written and visual materials, with worked examples. If the connections between chemical equations, diagrams and analogies are not explicitly made in teaching materials, the learner may be able to follow the teacher's example in class, but may be unable to apply the strategy to a final-exam question. So any intervention in electrochemistry should not only provide re-instruction of the material - but also draw out misconceptions, make comparisons between galvanic and electrolytic cells and explicitly link symbolic, particulate and macroscopic representations [7,20,21].

Theoretical and pedagogical foundations for collaborative teaching

Collaborative teaching is based on pedagogies evidence by constructivist and socio-cultural theories of learning. In constructivist approaches, the learning process involves students actively constructing meaning as a result of reorganising what they already understand, rather than passively acquiring knowledge from the teacher [22]. In chemistry, this is important given students bring alternate ideas about particles, charge, current and chemical change. From a socio-cultural perspective learning occurs via interaction, language and supported participation with others [23]. These insights mean a collaborative teaching session with course lecturers and guest lecturer can offer new ways to explain and understand, to model expert ways of thinking and enable a comparison between student and disciplinary explanations.

Co-teaching and collaborative teaching are also backed up by higher-education studies. Cook and Friend describe co-teaching as an sharing of teaching roles in which teachers collaborate to plan, implement and assess teaching to leverage their expertise [24]. Recent reviews indicate the effectiveness of collaborative teaching for enhancing learning outcomes, given that the instructors coordinate roles, clarify expectations and offer complementary explanations and support [10,11]. In CHM096, the presence of multiple lecturers (course lecturers and a guest lecturer) is justified on pedagogical grounds because there are a number of highrisk conceptual points in electrochemistry. Multiple lecturers can more readily emphasise the same key ideas from different perspectives, offer new examples and separate technical tips and tricks for the examination from conceptual understanding.

The benefits of collaboration also align with evidence on active and cooperative learning. In higher education, cooperative learning practices are linked to higher success, motivation and interpersonal support if positive interdependence and individual accountability are implemented around a learning task [25]. Comprehensive reviews of active learning in STEM disciplines indicate that students generally fare better where they have opportunities for practice, feedback and interactive cognitive engagement with the learning task rather than simply being lectured [9,15,26]. Research on chemistry-specific innovations such as peer-led team learning and process-oriented guided inquiry learning also indicates that meaningful interaction around chemical problems can be beneficial for performance and retention in large introductory chemistry classes [15,27]. So, a collaborative electrochemistry course is likely to perform best when it involves more than explanation and includes discussion and practice, brief levels of assessment for learning and student verbalisation.

Guided problem solving, feedback and assessment alignment

Electrochemistry is inextricably linked with problem solving, as students apply new concepts to half-equations, cell diagrams, standard potentials and the products of electrolysis reactions. This means that active teaching approaches are enhanced when examples are then followed by practice that progressively shifts control towards the student [15,26,28]. Such scaffolds may start with the lecturer identifying oxidation and reduction, then have students complete a similar half-equation, then interpret E_{red} information to predict spontaneity, and so on to an examination-level question of E_{cell}. This approach is not repetition but cognitive support, and facilitates connections between practice and principles.

Alignment of assessment is also key to the analysis of post-programme outcomes. Constructive alignment suggests that learning outcomes, teaching activities and assessment tasks be aligned so that students engage in the same modes of thinking that they will be assessed upon [13]. In the current manuscript, the CHM096 May 2025 exam included multiple choice questions and structured questions about half-equations, spontaneity of reactions, E_{cell} calculations and electrolysis equations, to assess electrochemistry. If the joint teaching program focused on redox reactions, galvanic cells and standard electrode potential then its success is not only gauged by the student feedback but also by how it prepared them for the aforementioned aligned assessment tasks. This means that Q4 and Q5 are relevant formative indicators, although the records from the survey do not distinguish all subparts.

There's also feedback. According to formative assessment studies, learning is enhanced when learners get timely feedback on their progress towards a learning goal, and when teachers and learners use the feedback to guide teaching and learning [28]. In electrochemistry, formative feedback is valuable as errors can be due to: lack of understanding of the oxidation-reduce process, choosing the wrong half-cell for the cathode, sign error when calculating E_{cell}, or being unable to balance atoms and charges. A collaborative teaching session can provide clarification but the present findings indicate that future programmes should provide more diagnostic exercises on galvanic-cell reasoning, standard electrode potential and exam-type calculations.

Student perception, confidence and affective outcomes

Perception data is a valuable measure in educational program evaluation as student confidence, clarity and perceived utility of a course can impact on their persistence and a desire to tackle difficult problems. Research on learning motivation suggests that there are different levels of participation (extrinsic and more intrinsic), and that perceptions of competence and relatedness may encourage students to engage in more productive learning activities [29]. In chemistry teaching, practice may be deferred by students who perceive a topic as too challenging, unless the instruction enables them to get a taste of success and increments their confidence. The positive feedback ratings therefore demonstrate more than this study's students found the teaching activity interesting; rather, they show that the group teaching activity may have assisted the students' perception that electrochemistry is accessible.

Perception information should be treated with care, however. Students may be satisfied even though they fail to learn concepts, and their confidence may increase more rapidly than their ability to solve problems. This is where the combined feedback/assessment evidence is useful. Student responses to the programme were overwhelmingly positive, but the areas of relatively lower ratings were student satisfaction with answering electrochemistry questions, final-exam readiness, standard electrode potential and galvanic cells. These are the areas known to be conceptually challenging and sensitive to examination [1,3–5]. The correlation thus suggests a balanced view: the programme was presumably successful in reducing some barriers, and was generally well-received, but needs to reinforce higher-order electrochemical reasoning skills.

Synthesis and research gap

The literature implies that electrochemistry is hard because it involves abstract thinking, microscopic thinking, symbol manipulation and quantitative judgement [14,18–21]. It also demonstrates that collaborative, active and cooperative teaching activities can enhance student engagement and performance in the context of appropriate interaction and assessment procedures [9,11,14,25–27]. But there are fewer studies of small-scale collaborative teaching projects in foundation chemistry that have been measured using post-programme surveys and examination results. The present study responds to this need by relating student feedback on a collaborative electrochemistry programme to the content and results of the CHM096 examination.

The review also suggests that a conservative evaluative approach is warranted. Given the documentary and post-programme nature of the evidence, it should not make causal inferences. The review suggests, however, that it can be explored whether student feedback, examination coverage and cohort attainment were not incompatible with a positive pedagogic contribution. As such, the current study adds to chemistry education practice by detailing perceptions a collaborative teaching intervention in foundation electrochemistry and the display of

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue V May 2026

post-programme electrochemistry attainment in an assessment context that required reasoning about redox reactions, galvanic cells, standard potential and electrolysis (deionisation).

Programme Context

Based on Figure 1, the documents on the programme present the intervention as a collaborative teaching program based on the subject of electrochemistry in CHM096 Foundation Chemistry II. This session was aimed at redox reactions, the existence of galvanic cells and the standard electrode potential which was arranged to assist in consolidating the knowledge of students before the final test. The document also suggests that CHM096 lecturers with a guest lecturer engaged in an online teaching mode were involved in the activity. Even though there are administrative inconsistencies noted in the paperwork, it is nonetheless valuable in forming the standard of the pedagogical scope and the purpose of the programme.

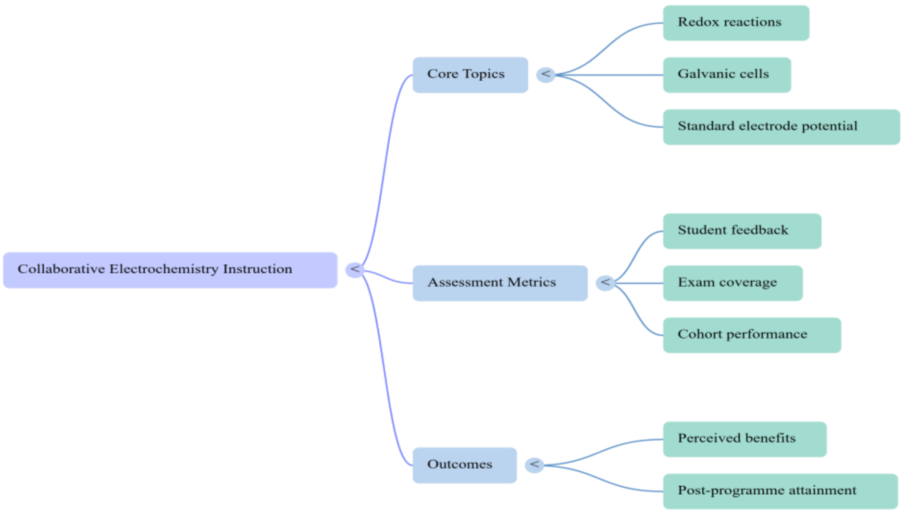

Figure 1: Evaluation framework of the collaborative teaching programme

METHODOLOGY

Research design and data sources

This research paper had a descriptive, document-based assessment design. The review was enlightened by documentary, evaluation and assessment related documents pertaining to the programme implementation and outcomes. These materials were applied to the perception of students, the level of assessment consistency and the performance trend of cohorts in electrochemistry.

The process of analysis was done in three phases. The initial phase summarized student feedback ratings, completion behaviour, mix of participants and open-ended suggestions. The second phase was the electrochemistry content in the CHM096 assessment books. The third phase examined performance records at cohort level, at question level with special consideration to the electrochemistry structured section (Question 4 and Question 5). Since the records available only record by whole question and not subpart, the analysis had the ability to make a direct test of total Q4 and total Q5 marks but could not make separate tests of Q4(b) or Q5(a). There was the same case with the combined objective-section marks which could not be split and extract MCQ 8-11 individually. To that end, the combined structured score Q4 + Q5 was the most justifiable post-programme examination measure of electrochemistry in the available records.

RESULTS

Student feedback on the collaborative teaching programme

Based on Table 1 and Figure 2, 87 students have answered the programme feedback summary. Amongst these 86 out of 87 students said that they continued with the programme to the end. The overall mean score of all the rating items was approximately 4.70 out of 5, and 95.9 percent of all ratings were 4 or 5. The highest rated were the achievement of programme objectives (4.80), the mastery of the topic by the speaker (4.80), the easy implementation (4.79), the appropriate duration (4.77) and the clear and systematic explanation (4.75). Meanwhile, confidence with answering electrochemistry questions following the programme scored relatively smaller, yet significant (4.55), as well as helpful in final-exam preparation (4.56), understanding of the standard electrode potential (4.61), and understanding of galvanic cells (4.62). There were more positive answers given to open-ended questions, where a lot of students reported having no significant issues. Dominantly the suggestions that did emerge were to have more face time sessions, more examples, more programmes like this one in the future, better matching handouts, and more technical stability. The sample of sample participants was a mixture of 52 students of science and 35 students of engineering.

Table 1. Summary of student feedback findings for the collaborative teaching programme

Indicator	**Value**
Total responses	87
Students who followed the programme until the end	86 of 87
Overall mean rating	4.70 / 5
Ratings of 4 or 5	95.9%
Highest-rated dimensions	Programme achieved objectives (4.80); speaker mastery (4.80); programme ran smoothly (4.79); duration suitable (4.77); explanation clear and systematic (4.75)
Relatively lower but still positive areas	Confidence in answering electrochemistry questions (4.55); final-exam preparation (4.56); clarity on standard electrode potential (4.61); clarity on galvanic cells (4.62)
Participant mix	Science: 52; Engineering: 35
Main open-ended suggestions	More face-to-face sessions; more examples; more similar programmes; better-aligned handouts; improved technical stability

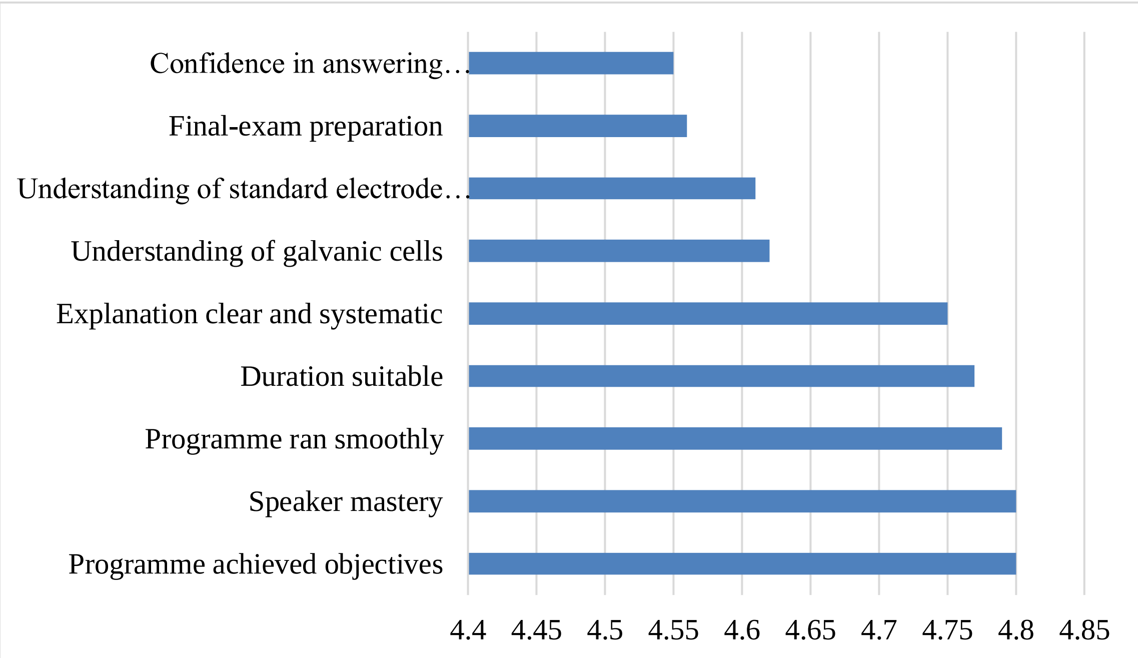

Figure 2. Student feedback ratings for the collaborative teaching programme

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue V May 2026

Electrochemistry coverage in the CHM096 final examination

According to the assessment documentation of CHM096, Electrochemistry is the topic Topic 4 which will be allotted 20 marks on the final examination. The complete May 2025 examination paper affirms that the electrochemistry is tested by MCQ 8-11 and the structured questions under Question 4 and Question 5. The objective part tests the concepts of oxidation-reduction, half equations balancing, interpretation of standard reduction potentials, and concepts of electrolysis (Table 2 and Figure 3). Q4(a) in the structured section involves a balanced reduction half-equation in acidic condition, Q4(b) involves students knowledge to detect the spontaneity using standard reduction potentials, Q5(a) involves calculation of the E_{cell} of a Zn^{2+}/Zn and standard hydrogen electrode galvanic cell, and Q5(b) involves half-reactions and an overall equation of electrolysis of aqueous zinc sulfate. The most laborious electrochemistry questions are thus in the structured part, particularly, Q4(b) and Q5(a), which are worth 5 marks each.

Table 2. Electrochemistry coverage in the CHM096 May 2025 final examination

Exam component	Question(s)	Electrochemistry focus	Marks
Part A (objective)	Q8	Oxidising agent in a redox reaction	1
Part A (objective)	Q9	Balanced half-equation in acidic medium	1
Part A (objective)	Q10	Strongest reducing agent from E°_{red} data	1
Part A (objective)	Q11	Electrolysis of bauxite / aluminium extraction	1
Part B (structured)	Q4(a)	Balanced reduction half-equation for N_2O in acidic condition	3
Part B (structured)	Q4(b)	Spontaneity from standard reduction potentials	5
Part B (structured)	Q5(a)	E_{cell} calculation for $Zn^{2+/}Zn$ and SHE galvanic cell	5
Part B (structured)	Q5(b)	Electrolysis of aqueous $ZnSO_4$	3

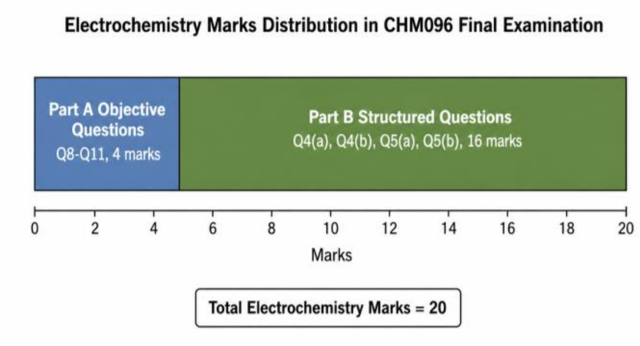

Figure 3. Electrochemistry coverage in the CHM096 final examination

Post-programme electrochemistry attainment in the 2025 cohorts

The report on the cohort-based 2025 performance (Table 3 and Figure 4) records involved the analysis of 100 students in the following cohorts: PI009E23, PI009E24, PI080S55 and PI080S56. The analysis of the electrochemistry structured-question was performed with a set of 99 valid scripts, whereas one S56 record lacked usable item-level Q4 and Q5 marks. The results provided in these 99 scripts give an average Q4 score of 4.41 of 8, an average Q5 score of 3.48 of 8 and an overall average of Q4 + Q5 of 7.90 of 16 which is equal to 49.4. The average value of the combined scores was 8/16. In distributional terms, 53.5% of students scored 8/16 or above, 35.4% scored 10/16 or above, and 17.2% scored 12/16 or above.

Table 3. Post-programme electrochemistry structured-question performance in the 2025 cohorts

Cohort	***n***	**Mean Q4 / 8**	**Mean Q5 / 8**	**Mean Q4 + Q5 / 16 (%)**
PI009E23	25	4.56	3.28	7.84 (49.0%)
PI009E24	27	4.26	2.81	7.07 (44.2%)
PI080S55	23	4.52	4.52	9.04 (56.5%)
PI080S56	24*	4.33	3.46	7.79 (48.7%)
Overall	**99**	**4.41**	**3.48**	**7.90 (49.4%)**

**One S56 record did not contain usable item-level Q4 and Q5 marks.*

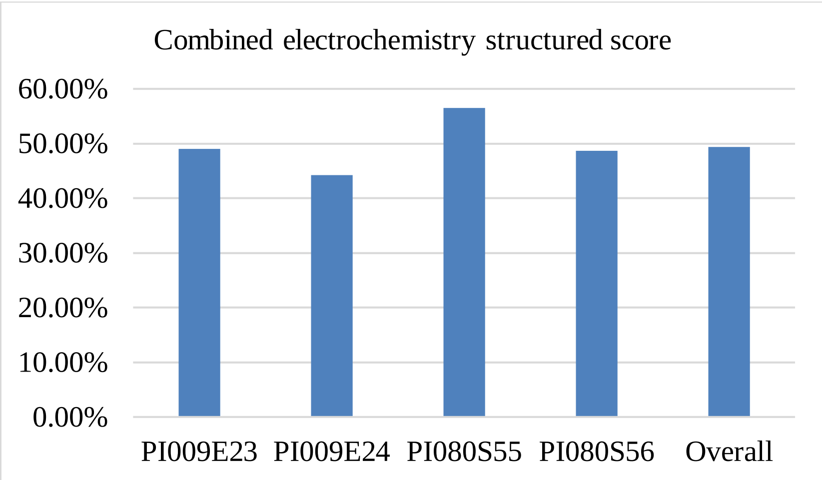

Figure 4. Post-programme electrochemistry performance by cohort

There was significant difference in cohort level performance. PI080S55 achieved the best structured electrochemistry performance at 9.04 out of 16 (56.5%), although PI009E24 had the lowest combined mean performance at 7.07 out of 16 (44.2%). When combined by stream and scaling to an average of the science groups of 8.40 out of 16 (52.5%), the engineering groups showed an average of 7.44 out of 16 (46.5). Another positive trend also came out: the electrochemistry structured section, being normalised by the number of marks available, performed higher than the rest of the structured questions overall (40.5%). This implies that among the post-programme 2025 evidences, electrochemistry was not the least part of the structured final examination.

DISCUSSION

All the evidence points to the collaborative teaching program as one that created a beneficial learning experience in the area of electrochemistry in CHM096. First, student comments were highly positive. Students indicated that the programme achieved its goals, it was effectively presented and presented by a speaker who was well knowledgeable on the topic. These results are in line with larger literature in higher-education settings that collaborative and active pedagogies can facilitate engagement and learning in challenging STEM environments [8–11].

Second, the post-programme profile as evidenced by the examination is encouraging. There was average attainment in the electrochemistry structured section, but overall further achieved over the rest of the structured section as well. This is not a trivial finding since the orderly electrochemistry questions needed to be remembered beyond the recollection of facts. They measured half-equation writing and spontaneity reasoning, galvanic-cell calculation, and electrolysis products all of which are known to be challenges to students [1–7]. That the post-programme result in this section was not lower than other structured questions also substantiates a cautious positive point of view.

Simultaneously, there are also obvious spheres of improvement which the findings mark. The least relative feedback ratings were centered in confidence in responding to the questions regarding electrochemistry, galvanic cell, standard electrode potential and final-exam preparation. Such spaces go hand in hand with higher-order requirements of Q4(b) and Q5(a) in which students were to determine standard reduction potentials, as well as compute E_{cell}. Q5 weakly also compared with Q4 and there was an indication that galvanic-cell reasoning and electrochemical calculation was more daunting than redox and half-equation problems were. This would also suggest that the next phases of the programme would have the overall structure, but more guided problem-solving, worked examples, exam-like practising, and specific scaffolding around galvanic cells, standard electrode potentials and electrolysis.

The current research is also to be taken with a grain of salt. The evidence of student feedback was in form of a summary and not item-level data. The documentation of the programme had certain administrative discrepancies. Q4(b) and Q5(a) were not differentiated among the rest of Q4 and Q5 of the performance records of 2025, and MCQ 8 to 11 were not isolable out of the objectives item bank. Moreover, previous-cohort data reflected a different structure of the examination and thus could not be directly compared (item-level) with the 2025 paper. These results thus affirm a conclusion of positive post-programme achievement and a positive student perception, but are not sufficient on their own to trace on to strict causal effect.

CONCLUSION

This paper presents a journal-like review of one of the collaborative teaching projects aimed at facilitating the learning of electrochemistry in CHM096 Foundation Chemistry II. The evidence shows the programme was highly accepted by the students and attainments of students in the electrochemistry structured part of the end examination were moderate yet encouraging even after the programme. Notably, the electrochemistry structured section performance was better than performance on all the other structured questions and this may imply that electrochemistry was not a relatively low post-programme performance area.

Collaborative teaching was received well, and linked with the promotion of post-programme electrochemistry achievement, especially in one subject area that students generally report finding conceptually challenging. Nevertheless, it is also found that further narrowly-focused reinforcement is required in the field of galvanic-cell reasoning, standard electrode potential, electrolysis and examination-type electrochemistry problems solving. The solutions in the future should maintain the characteristics of the collaborative model with an addition of more explicit conceptual scaffold and guided assessment practice within these higher subtopics.

Ethical Considerations

No potential conflicts of interest.

Data Availability

Not available. Still under research stage.

REFERENCES

1. Garnett, P. J., & Treagust, D. F. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electrochemical (galvanic) and electrolytic cells. Journal of Research in Science Teaching, 29(10), 1079–1099. https://doi.org/10.1002/TEA.3660291006;SUBPAGE:STRING:ABSTRACT;WEBSITE:WEBSITE:PERICLES;WGROUP:STRING:PUBLICATION
2. Tien, L. T., & Arshad, M. Y. (2009). Miskonsepsi Pelajar Tingkatan Empat Mengenai Elektrokimia: Misconception in Electrochemistry amongst Form Four Students. Journal of Science and Mathematics Letters, 1(2), 52–64. https://ejournal.upsi.edu.my/index.php/JSML/article/view/375

3. Özkaya, A. R. (2002). Conceptual Difficulties Experienced by Prospective Teachers in Electrochemistry: Half-Cell Potential, Cell Potential, and Chemical and Electrochemical Equilibrium in Galvanic Cells. Journal of Chemical Education, 79(6), 735. https://doi.org/10.1021/ED079P735
4. Rahayu, S., Treagust, D. F., Chandrasegaran, A. L., Kita, M., & Ibnua, S. (2011). Assessment of electrochemical concepts: a comparative study involving senior high-school students in Indonesia and Japan. Research in Science & Technological Education, 29(2), 169–188. https://doi.org/10.1080/02635143.2010.536949
5. Sanger, M. J., & Greenbowe, T. J. (1997). Students' Misconceptions in Electrochemistry Regarding Current Flow in Electrolyte Solutions and the Salt Bridge. Journal of Chemical Education, 74(7), 819–823. https://doi.org/10.1021/ED074P819
6. Sanger, M. J., & Greenbowe, T. J. (1999). An Analysis of College Chemistry Textbooks As Sources of Misconceptions and Errors in Electrochemistry. Journal of Chemical Education, 76(6), 853–860. https://doi.org/10.1021/ED076P853
7. Özkaya, A. R., Üce, M., Sariçayir, H., & Şahin, M. (2006). Effectiveness of Conceptual Change-Oriented Teaching Strategy To Improve Students' Understanding of Galvanic Cells. Journal of Chemical Education, 83(11), 1719–1723. https://doi.org/10.1021/ED083P1719
8. Brush, S. S. (2024). Investigating Student Performance, Course Completion, and Student Perceptions in the Blended-Flipped Teaching (BFT) Model with Collaborative Teaching Teams (CTT) in Large-Sized College Chemistry Classrooms. Journal of Chemical Education, 101(11), 4541–4551. https://doi.org/10.1021/ACS.JCHEMED.3C01026
9. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America, 111(23), 8410–8415. https://doi.org/10.1073/PNAS.1319030111;WGROUP:STRING:PUBLICATION
10. Newell, C., & Bain, A. (2018). Team-Based Collaboration in Higher Education Learning and Teaching. SpringerBriefs in Education. https://doi.org/10.1007/978-981-13-1855-9
11. Vembye, M. H., Weiss, F., & Hamilton Bhat, B. (2024). The Effects of Co-Teaching and Related Collaborative Models of Instruction on Student Achievement: A Systematic Review and Meta-Analysis. Review of Educational Research, 94(3), 376–422. https://doi.org/10.3102/00346543231186588;REQUESTEDJOURNAL:JOURNAL:RERA;WEBSITE:WEBSITE:SAGE;ISSUE:ISSUE:DOI
12. Nor Hashim, N. Z., & Hanibah, H. (2024). Exploring Integrated Online Instructional Approaches Among The Foundation Chemistry I in Malaysia by Utilizing Youtube and Google Classroom. Asian Journal of Assessment in Teaching and Learning. https://ejournal.upsi.edu.my/index.php/AJATeL/article/view/9184/4956
13. Biggs, J. (1996). Enhancing teaching through constructive alignment. Higher Education, 32(3), 347–364. https://doi.org/10.1007/BF00138871/METRICS
14. Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. Journal of Computer Assisted Learning, 7(2), 75–83. https://doi.org/10.1111/J.1365-2729.1991.TB00230.X;WGROUP:STRING:PUBLICATION
15. Lewis, S. E. (2011). Retention and Reform: An Evaluation of Peer-Led Team Learning. Journal of Chemical Education, 88(6), 703–707. https://doi.org/10.1021/ED100689M
16. Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing demand. Journal of Chemical Education, 70(9), 701–705. https://doi.org/10.1021/ED070P701
17. Gilbert, J. K., & Treagust, D. (Eds.). (2009). Multiple Representations in Chemical Education. Models and Modeling in Science Education, 4. https://doi.org/10.1007/978-1-4020-8872-8
18. Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. Chemistry Education Research and Practice, 14(2), 156–168. https://doi.org/10.1039/C3RP00012E
19. Talanquer, V. (2011). Macro, Submicro, and Symbolic: The many faces of the chemistry "triplet". International Journal of Science Education, 33(2), 179–195. https://doi.org/10.1080/09500690903386435

20. Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. International Journal of Science Education, 25(11), 1353–1368. https://doi.org/10.1080/0950069032000070306
21. John, G., & David, F. T. (2009). Multiple Representations in Chemical Education. Models and Modeling in Science Education, 4, 1–369. https://doi.org/10.1007/978-1-4020-8872-8
22. Bodner, G. M. (1986). Constructivism: A theory of knowledge. Journal of Chemical Education, 63(10), 873–878. https://doi.org/10.1021/ED063P873
23. VYGOTSKY, L. S. (2019). Mind in Society. Mind in Society. https://doi.org/10.2307/J.CTVJF9VZ4
24. Cook, L., & Friend, M. (1995). Co-Teaching: Guidelines for Creating Effective Practices. Focus on Exceptional Children, 28(3), 1–16.
25. Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative Learning Returns To College What Evidence Is There That It Works? Change: The Magazine of Higher Learning, 205–212. https://doi.org/10.1080/00091389809602629
26. Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231. https://doi.org/10.1002/J.2168-9830.2004.TB00809.X;ISSUE:ISSUE:DOI
27. Walker, L., & Warfa, A. R. M. (2017). Process oriented guided inquiry learning (POGIL®) marginally effects student achievement measures but substantially increases the odds of passing a course. PLoS ONE, 12(10). https://doi.org/10.1371/JOURNAL.PONE.0186203
28. Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. Assessment in Education: Principles, Policy & Practice, 21(1), 7–74. https://doi.org/10.1080/0969595980050102
29. Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. Contemporary Educational Psychology, 25(1), 54–67. https://doi.org/10.1006/CEPS.1999.1020