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ENHANCING COMMUNICATION AND LEARNING EFFECTIVENESS IN PHYSICS VIA PEER INSTRUCTION INTEGRATED WITH CLOUDCLASSROOM (CCR): A CASE STUDY IN VIETNAM

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ABSTRACT

This quasi-experimental study integrates Peer Instruction (PI) method with the CloudClassRoom (CCR) platform to improve learning outcomes in teaching a lesson titled "Work, Energy, and Power" to 10th-grade physics students. The intervention took place over two 45-minute classes with 41 students at a high school in Vietnam, selected through convenience sampling. The primary aim was to improve students' communication competence while enhancing learning engagement. The study used a mixed-methods design, combining pre- and post-intervention Likert scale self-assessment questionnaires with analysis of student discussions and comprehension questions on the CCR platform. Self-assessment results showed that PI with CCR significantly enhanced students' ability to identify problems and engage in meaningful discussions through verbal and non-verbal interactions. Two communication indicators showed significant improvements with medium to large effect sizes. Furthermore, the analysis of knowledge acquisition demonstrated that the structured series of inquiry-based questions in the lesson substantially improved the accuracy of students' answers, with correctness rising from less than 30% to over 70%. Despite limitations such as a small sample size, limited generalizability, and a short intervention (two class periods), the study offers empirical support for integrating PI and CCR as a viable strategy for enhancing physics education in Vietnamese high schools.

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Keywords: Peer Instruction (PI); CloudClassRoom (CCR); communication; physics education; high school

INTRODUCTION

Ensuring equitable access to high-quality education and meaningful learning opportunities remains a global challenge (UNESCO, 2023). Within science education, effective learning requires students to not only develop conceptual understanding but also to engage in scientific reasoning, collaborative discussion, and problem-solving. Increasingly, researchers have been exploring various technology-enhanced teaching approaches to support student engagement, comprehension, and scientific literacy (UNESCO, 2023; Sayadi & Pangandaman, 2025). However, access to digital technologies does not necessarily result in more equitable learning. Students differ in how productively they engage with digital tools. In a study of upper secondary students, academically successful students tended to use technology more effectively for learning, whereas

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disengaged or off-task technology use was associated with poorer academic performance (Bergdahl et al., 2020). Ensuring that digital technologies support rather than distract from learning therefore depends less on access to devices than on utilizing pedagogical approaches that structure student interaction and give technology a clear instructional purpose.

Peer Instruction (PI), which emphasizes conceptual understanding by structuring collaborative discussion around conceptual questions, is one such approach (Mazur, 1997). A substantial body of research shows that PI improves conceptual learning and enhances students' performance on both qualitative (Crouch & Mazur, 2001; Fagen et al., 2002; Yıldırım & Canpolat, 2019; Olpak & Yılmaz, 2022) and quantitative problems (Crouch & Mazur, 2001; Crouch et al., 2007). PI enables students to exchange ideas and discuss conceptual questions, which concurrently develops academic communication competence (Vickrey et al., 2015). At its core, PI focuses on using questions to foster a discussion-driven environment that enhances conceptual understanding, captures students' attention, and encourages interaction during the lesson. The effectiveness of PI depends on well-designed sequences of conceptual questions that expose misconceptions and stimulate productive scientific discourse, together with the rapid collection of responses, immediate feedback, and structured peer discussion (Mazur, 1997; Crouch & Mazur, 2001; Crouch et al., 2007; Vickrey et al., 2015). Variations of PI have been widely documented across different learning contexts (Zingaro & Porter, 2014; Chou & Lin, 2015; Michinov et al., 2015), and comparative studies show that approaches combining peer discussion with instructor explanation tend to produce the highest learning gains, especially among average and weaker students (Smith et al., 2011; Zingaro & Porter, 2014).

In PI, teachers typically allocate roughly one-third to one-half of the class time for conceptual question testing (Crouch et al., 2007). Conceptual questions can be presented verbally, via slide presentations, or on the blackboard (Chou & Lin, 2015). Student responses can be collected by raising hands (Crouch et al., 2007) or answer cards (Gok, 2015), or by using clicker software (Pearson, 2019) or other digital tools on personal devices (Chou & Lin, 2015). The choice of response tool is determined by the learning environment, lesson objectives, and the specific PI implementation selected by the instructor (Crouch et al., 2007). While response collection can be conducted through physical actions, technology-based response systems are increasingly preferred due to their efficiency, immediacy of feedback, and capacity to rapidly capture whole-class thinking (Chou & Lin, 2015; Pearson, 2019; Olpak & Yılmaz, 2022). Currently, clickers are regarded as the most widely used feedback technology in applied studies (Olpak & Yılmaz, 2022), highlighting their central role in collecting rapid, class-wide responses.

Traditional hardware has well-documented limitations, including cost, maintenance demands, and restricted functionality (Chien et al., 2015; Pearson, 2019; Henderson & Chambers, 2024). With the widespread adoption of mobile and cloud-based platforms, there is an opportunity to overcome these barriers. CloudClassRoom (CCR) is an online platform that facilitates interactive questioning, response collection, and real-time synthesis of student answers to support instructors in the teaching process (Cheng et al., 2022). In addition, the platform supports teacher–student interaction during instruction by being free and easily accessible via electronic devices, and by offering diverse functions for organizing instruction, making it well-suited for PI (Chien & Chang, 2015). Beyond basic response collection, CCR supports multiple question formats and can automatically cluster similar or divergent responses, enabling instructors to strategically organize text-based discussion groups based on differing viewpoints—a feature that aligns well with the dialogic nature of PI. Such grouping promotes richer peer interaction, critical reasoning, and the articulation of scientific arguments compared with traditional fixed-seating discussion formats (Chan & Chang, 2018; Chang, 2019). This diversity of interaction, supported by CCR's capacity to facilitate both oral and written modes of discussion, provides rich opportunities for developing students' communication competence (Chan & Chang, 2018; Wicaksono et al., 2022).

Initial evidence suggests that integrating PI with CCR may help students develop conceptual understanding in physics, as group discussions enable learners to articulate reasoning, challenge or confirm their ideas, and refine their conceptual models (Sui et al., 2024). Consequently, teachers can more readily diagnose students' misconceptions and facilitate more accurate conceptual refinement. Although there is substantial evidence supporting the effectiveness of PI (Cummings & Roberts, 2008; Turpen & Finkelstein, 2009; Aslamiyah & Tyas, 2025; Gjerde & Hagane, 2024) and growing evidence on the use of digital response tools (Chien & Chang, 2015; Sayer et al., 2016; Wuttiprom et al., 2017; Pearson, 2019; Hender-

son & Chambers, 2024), previous research has examined PI and technology-supported instruction across a range of contexts, with comparatively less attention to the integration of PI with cloud-based platforms to support communication competence. Moreover, empirical research that integrates PI with cloud-based platforms while simultaneously examining both conceptual learning and communication competence remains limited, particularly in the Vietnamese high school context.

The need for such evidence is especially clear in Vietnam, where the 2018 General Education Curriculum (Ministry of Education and Training, 2018) places the development of students' key competencies and qualities at the center of general education. Accordingly, the physics curriculum extends beyond the acquisition of conceptual knowledge to include the development of scientific competence and skills such as problem-solving, communication, and collaboration. These curricular priorities provide an important context for examining how technology-enhanced pedagogical approaches can be designed and implemented to support students' learning in physics. Investigating the integration of PI and CCR in the Vietnamese upper-secondary context may therefore contribute to a broader understanding of how digital technologies can be integrated into science teaching to support the meaningful and equitable acquisition of key competencies.

This study aims to extend previous findings by implementing a PI model supported by the CCR platform in a Vietnamese Grade 10 physics classroom. Specifically, it posits the following research question: To what extent does integrating Peer Instruction (PI) with the CloudClassRoom (CCR) platform enhance students' communication competence and conceptual understanding during a lesson titled "Work, Energy, and Power"? By doing so, the study contributes pedagogically by illustrating the application of a low-cost, technology-supported active learning model, and contextually by providing classroom-level evidence from a Vietnamese high school, thereby informing physics education practices in Southeast Asia and broader research on technology-supported active learning.

METHODS

As the intervention was implemented in an established classroom during regular instruction, a single-group pre–post design was adopted. This method allowed for the measurement of students' communication competence and learning outcomes before and after the intervention.

The study involved 41 Grade 10 students (20 male and 21 female) from a high school in Ho Chi Minh City, Vietnam. Ho Chi Minh City has been active in implementing digital education initiatives, making it a relevant setting for research on technology-supported active learning. Participants were selected using convenience sampling, which is appropriate when the sample is drawn from naturally existing classrooms that are accessible and willing to participate (Etikan, 2016).

The participating physics class was selected because the school was implementing the 2018 General Education Curriculum, the national framework for general education that defines educational goals, expected student competencies and qualities, educational content, teaching methods, and assessment (Ministry of Education and Training, 2018). The school also permitted the integration of PI and CCR into regular classroom instruction. In the selected class, first-semester academic performance was generally moderate, with one student achieving excellent results, 22 performing well, 17 meeting the required standards, and one falling short of expectations.

Students were accustomed to using mobile phones for classroom activities, such as answering multiple-choice questions via Kahoot and Quizizz. However, they had no prior experience using educational technology software for learning new content, especially in physics. After receiving guidance on how to use the platform at home, most students quickly learned the necessary features for the CCR lesson, making it suitable for classroom implementation.

PI–CCR Implementation Procedure

During the intervention, the topic of work, energy, and power was taught using a modified PI approach supported by the CCR platform. The original PI framework typically follows a lecture–question–peer discussion cycle and recommends using specific percentage-based comprehension thresholds to guide instructional decisions (Crouch & Mazur, 2001; Mazur, 1997). However, previous studies have shown that teachers often adapt PI procedures to better fit specific classroom contexts and instructional goals (Dancy & Henderson, 2010). Based on these considerations, the present study implemented an adapted PI procedure (Figure 1).

First, instead of using short in-class lectures as in the traditional PI model, students were required to review part of the learning materials at home through a set of guiding questions prepared by the teacher.

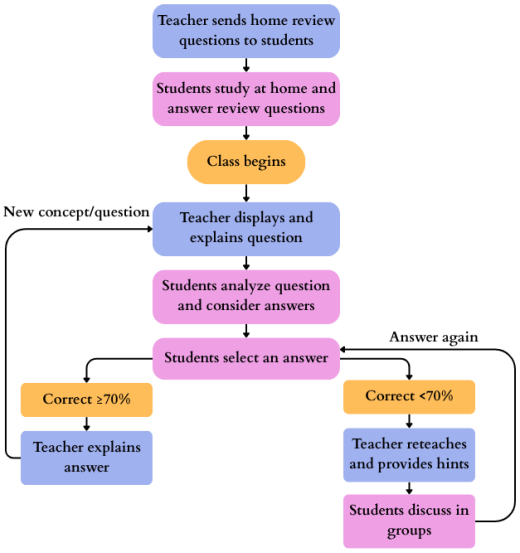


Figure 1. Flowchart of the PI Procedure Used in This Study

This preparation aimed to familiarize students with the fundamental concepts before classroom discussion and to allow more classroom time for conceptual interaction. Such an approach aligns with the recommendation of Crouch et al. (2007) that pre-class preparation can be used to enhance the effectiveness of PI activities.

Second, during the lesson, the teacher presented conceptual questions through the CCR platform. Students selected their answers individually on their mobile devices, and the aggregated responses were immediately displayed on the classroom screen. This real-time visualization allowed both the teacher and students to quickly identify the distribution of responses and the level of conceptual understanding within the class.

Third, discussion groups were formed automatically by the CCR and students engaged in written peer discussion through the CCR platform. After viewing the distribution of responses, students exchanged their reasoning with peers, particularly classmates who had selected different answers. Students could explain, question, challenge, or support their peers' answers using written messages. The CCR platform automatically recorded these written exchanges, which were subsequently analyzed as qualitative data to examine patterns of student interaction and communication. Previous studies have shown that combining peer discussion with instructor clarification can produce higher learning gains than using either strategy alone (Smith et al., 2011; Zingaro & Porter, 2014).

Fourth, after the discussion period, students answered the same questions again through the CCR system. Changes in the response distribution allowed both the teacher and students to observe shifts in students' conceptual understanding.

Finally, the teacher clarified and summarized the key concepts based on students' responses and the discussion outcomes.

A further adaptation concerned the comprehension thresholds used in the PI process. In the original framework, when fewer than 30% of students answer a comprehension check correctly, the instructor is advised to reteach the concept before continuing the discussion. In this study, however, we did not apply the 30% lower-bound threshold. Instead, when class accuracy fell below 70%, students engaged in peer discussion with teacher guidance. This adjustment increased opportunities for student interaction and encouraged active engagement and knowledge construction, as students were required to justify their reasoning using both their pre-class preparation and the teacher's guiding prompts.

Communication competence was measured using a self-assessment questionnaire administered before and after the intervention to assess changes in students' communication performance. The questionnaire was aligned with the officially accepted indicators of communication competence in the 2018 General Education Curriculum and comprised five sub-dimensions (Ministry of Education and Training, 2018):

AT: Demonstrating an attitude of organizing and persuading others

CO: Identifying one's own responsibilities and actions

OB: Identifying the purpose, content, means, and attitude of communication

RF: Self-assessment

RL: Establishing and developing social relationships and resolving conflicts

All items were rated on a five-point Likert scale (1 = completely disagree to 5 = completely agree) (Likert, 1932). Internal consistency was assessed using Cronbach's alpha, and the coefficient exceeded 0.70, indicating acceptable reliability for research purposes (Cronbach, 1951).

In addition, students' written peer discussions during the intervention were automatically recorded by the CCR platform. These recorded dialogues constituted the qualitative dataset used to examine students' interaction patterns and

communication behaviors during the PI activities. Before the lesson, students also completed a home-preparation activity through Google Forms based on the assigned learning materials. Their responses were used as an indicator of their preparation before the lesson.

Results from students' multiple-choice and open-ended responses, along with transcripts of their written group discussions on the CCR platform, were analyzed using both quantitative and qualitative approaches to comprehensively evaluate the implementation of CCR-supported collaborative PI.

For the quantitative analysis, data from the pre- and post-test questionnaires on communication competence were processed in Microsoft Excel and JASP. Descriptive statistics summarized the results (Nick, 2007). To examine significant differences between pre- and post-test scores, the Wilcoxon signed-rank test was applied, which is appropriate for small sample sizes and nonparametric paired data (Wilcoxon, 1945). For the qualitative component, students' written dialogues within the 20 discussion groups were reviewed and categorized into distinct communication behavior groups (no chat, off-topic talk, talk without reasoning, and talk with reasoning). The frequency of each category was then calculated to identify prevailing interaction patterns during the CCR-supported lessons. This procedure follows the principles of quantitative content analysis, which allows qualitative data to be systematically described and quantified (Krippendorff, 2018).

RESULTS AND DISCUSSION

Table 1 presents the pre- and post-test comparisons, indicating that three indicators—CO3, OB3, and RL1—showed statistically significant differences at the 5% significance level ($|z| \geq 1.9$, $p < 0.05$).

Table 1. Wilcoxon Test Results for Students' Self-Assessment of Communication Competence Before and After the Intervention

Variables	Pre-test		Post-test		W	*z*	*p*	*r*
	M	SD	M	SD				
AT1	4.09	1.10	4.03	1.08	60.50	0.03	1.00	0.01
AT2	4.33	0.65	4.18	0.85	118.00	0.93	0.32	0.24
AT3	3.67	1.16	3.94	1.00	72.00	-0.93	0.35	-0.24
CO1	4.06	0.79	4.27	0.63	28.00	-1.54	0.10	-0.47
CO2	3.39	0.75	3.52	0.91	60.00	-0.78	0.42	-0.22
CO3	3.88	0.86	3.49	0.87	157.50	1.96	0.04*	0.50
CO4	4.24	0.87	3.91	0.98	154.00	1.83	0.06	0.47
OB1	3.58	0.83	3.61	0.86	52.00	-0.03	1.00	-0.01
OB2	3.76	0.79	3.58	1.03	110.00	0.60	0.53	0.16
OB3	2.91	0.81	3.49	1.06	41.00	-2.39	0.02*	-0.61
OB4	3.21	1.19	3.55	1.20	52.00	-1.46	0.14	-0.39
RF1	3.64	1.06	3.67	0.85	83.50	-0.09	0.95	-0.02
RL1	3.49	1.09	4.03	0.85	47.50	-2.15	0.03*	-0.55

*p < 0.05

Large effect sizes were observed for OB3 (r = -0.61) and RL1 (r = -0.55), reflecting substantial post-intervention increases. The most significant change was observed in indicator OB3: "I know how to use verbal combined with nonverbal means to present information, ideas, and to discuss, argue, and evaluate issues in science." The mean value increased from 2.91 to 3.49. This indicates that PI and CCR positively impacted students' communication competence through verbal means (oral group discussions and CCR-based discussions) and non-verbal means (gestures and actions during discussions). Research on Vietnamese students' participation in science classrooms has shown limited engagement in spoken-language classroom activities (Le & Nguyen, 2021). Thus, the teaching method effectively promotes communication and helps students develop the habit of using spoken language in classroom activities.

Indicator RL1, "I can recognize problems or conflicts between myself and my group mates and find appropriate ways to communicate and resolve them," also showed significant improvement, with the mean value increasing from 3.49 to 4.03 after the lesson. The PI method encourages students to exchange and discuss ideas to persuade others of their chosen answers. Such discussions can lead to conflicts, particularly when group members hold differing views, and they provide opportunities for students to practice resolving disagreements and handling opposing opinions constructively. This outcome aligns with research showing that structured peer discussions effectively foster critical thinking and argumentation skills (Knight & Wood, 2005). This finding further aligns with Basyah et al. (2021), who reported that students engaged in cooperative learning under the student team achievement division model demonstrated enhanced communication competence through structured peer interaction, negotiation, and the resolution of conflicting opinions. Studies in other educational contexts have also shown that when students participate in the PI method, explaining concepts to their peers not only reinforces their own understanding but also enhances collaboration and communication competence in group settings (Tullis & Goldstone, 2020; Rivadeneira & Inga, 2023).

Indicator CO3, "I often propose tasks that match my own strengths and capabilities when working in groups," also showed a relatively large effect size (r = 0.50); however, its mean score decreased after the lesson. The decrease in CO3 should be interpreted cautiously because the item concerns proposing tasks that match one's own strengths and capabilities, whereas the PI–CCR activities primarily involved discussing conceptual questions rather than assigning tasks or roles. Thus, this item may not have been closely aligned with the specific form of peer interaction implemented in the present study. Consequently, students may have had limited opportunities to apply or reflect on this aspect of group work competence. The results indicate that integrating PI with the CCR platform contributed to the development of students' communication competence. During PI cycles, students were required to articulate, justify, and defend their reasoning to their peers, creating repeated opportunities to practice expressing and negotiating ideas. This is reflected in improvements in indicators OB3 and RL1. These findings align with Wicaksono et al. (2022), who reported that combining face-to-face and technology-mediated peer discussions supports students in persuading each other when responding to conceptual questions, thereby diversifying classroom communication. This study extends prior evidence by demonstrating that communication-related indicators other than conceptual understanding can also be strengthened within a PI context. Meanwhile, the CCR platform provided a space for students to engage in written peer discussions, allowing them to respond to their peers, explain their reasoning, and consider different viewpoints through written dialogues. Matteucci et al. (2009) indicated that digital collaborative environments foster reflective communication, knowledge co-construction, and mutual negotiation. Similarly, Mohammadi et al. (2022) suggested that when students lead discussions themselves, they begin to think more carefully about how to explain, organize, and adjust their communication to solve problems and collaborate effectively. This supports the development of reflective thinking and self-regulated learning.

The main contribution of this result is that PI integrated with CCR is not only useful for supporting conceptual learning, as reported in previous studies, but can also be intentionally combined to develop specific components of communication competence. Moreover, the two discussion spaces—face-to-face discussions and written discussions on the CCR platform during class—complement each other. This coordination allows students' communication competence to be formed and develop naturally and purposefully.

However, because the intervention only covered two class periods, the observed changes mainly reflected the formation of initial awareness and communication habits, rather than stable or long-term development. Consequently, future studies should apply the combined PI and CCR model across a longer sequence of lessons or continuous competency-based themes to track more sustainable improvements in communication and collaboration.

To gain deeper insights into how students interacted during the PI activities supported by the CCR platform, we analyzed the nature and quality of their exchanges. This analysis aimed to identify discussion patterns that reflect varying levels of engagement, reasoning, and the application of scientific concepts. After analyzing students' written dialogues related to a question about the law of conservation of mechanical energy, we identified four main interaction patterns, shown in Figure *2*.

Pattern 1 – No chat: Students did not discuss or exchange on the platform at all; this pat-

tern was observed in one group.

Pattern 2 – Off-topic talk: Students did not discuss the assigned topic but instead engaged in off-topic private conversations; this pattern was observed in four groups.

Pattern 3 – Talk without reasoning: Students discussed the question but did not provide reasoning or explanations for their answer choices, simply asking one another for answers without justifying their selections; this pattern was observed in eight groups.

Pattern 4 – Talk with reasoning: Students discussed and explained their answers, referring to quantities and concepts related to the lesson; this pattern was observed in seven groups.

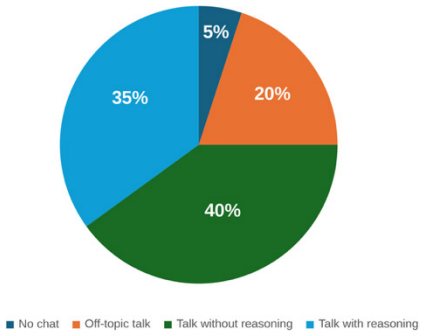


Figure 2. Distribution of Group Discussion Patterns on the CCR Platform (N = 20 groups)

Among the seven groups exhibiting Pattern 4, the proportion of exchanges related to the lesson content varied. Two groups devoted over 90% of their discussion to the lesson, two groups exceeded 60%, another two groups surpassed 50%, while one group had less than 50% of their interaction centered on the lesson material. In the two groups where over 90% of the discussion sentences were related to the lesson, all members actively engaged with the content from the outset. Meanwhile, groups with 50% and 80% lesson-related exchanges experienced initial distractions but quickly refocused on the lesson. Overall, these groups used written language effectively to present information, share ideas, and engage in discussions and arguments about the questions. Additionally, some students showed humility, were receptive to feedback, and enthusiastically supported their group members to reach consensus.

For example, in one group, students A and B enthusiastically debated concepts such as slope, height, and kinetic energy:

A: "Steeper slope → greater kinetic energy."

B: "But E's is steeper, right?"

A: "The other one's just a straight path… F's slide is lower but steeper."

A: "Lower → steeper."

B: "But the other one is higher."

A: "Yeah, but it goes down slowly… F goes down steeper."

Although this reasoning is not accurate regarding principles of physics, the discussion shows that students were trying to apply their knowledge and justify their choices.

Meanwhile, in another group, students C and D had a brief chat that reflected the lesson content correctly:

D: "Same height → same speed."

C: "Okkk."

These students demonstrated signs of independent critical thinking and had some foundational reasoning. However, their ability to articulate and elaborate on ideas through words remains limited. Comparable patterns were documented in research integrating PI with online social networks, where initial exchanges often consisted of short answer-seeking messages but gradually evolved into deeper reasoning and justification as students became accustomed to digital peer discussions (Zaid et al., 2018).

When comparing CCR discussion results with students' preparation at home, we found that groups with more effective discussions typically included members who had reviewed the material beforehand. Such preparation may have reduced distractions, improved focus, and enabled students to address their peers' questions more effectively. It may also have fostered confidence in expressing and defending their ideas, highlighting the importance of guiding students to study the lesson in advance.

Integrating the CCR tool into the group discussion process within the PI method improved student engagement and facilitated more structured peer interactions. The heterogeneous grouping feature, which matched students based on differing responses to a prior conceptual question, created opportunities for deeper discussions and critical analysis. The randomization function further expanded students' peer interaction networks by preventing them from engaging exclusively with familiar classmates and fostering more dynamic exchanges.

CCR also enabled teachers to monitor student interactions remotely and intervene, when necessary, without physically moving between groups (Wicaksono et al., 2022). This benefit aligns with findings from mobile collaborative informal learning studies grounded in activity theory, which emphasized that mobile devices

mediate teacher monitoring and coordination, enabling more effective orchestration of group activities (Baloch et al., 2012). Moreover, the multiple-choice and open-ended question formats provided by CCR (Wicaksono et al., 2022) effectively engaged students with conceptual physics content. Notably, students were already accustomed to using mobile devices for academic purposes in other subjects, which minimized technical difficulties and enhanced the effectiveness of CCR integration.

However, some challenges were informally observed during implementation. Students may initially spend more time exploring the tool's features rather than focusing on the discussion content. Additionally, some students may initially struggle to express their opinions clearly in writing. Nonetheless, these challenges may gradually be addressed as students become familiar with the tool and improve their discussion skills.

Within the findings related to students' discussion behavior on the CCR platform, three noteworthy points emerged. First, the use of CCR to form heterogeneous groups based on differing initial responses helped create productive cognitive conflict, encouraging students to explain and justify their reasoning more clearly during discussion. Second, the results highlight the important influence of pre-lesson preparation: groups whose members reviewed the material beforehand engaged in more focused, confident, and meaningful exchanges. Finally, CCR allowed teachers to monitor students' discussions in real time without physically moving between groups, making it easier to support and guide interactions when necessary.

In the experimental lesson, the teacher administered a set of four conceptual questions covering the following content: the transformation between kinetic and potential energy (Question 1, open-ended); the law of conservation of mechanical energy (Question 2, multiple-choice); and the application of the law of conservation of mechanical energy (Questions 3 and 5, multiple-choice). Students' responses to these questions could reflect the lesson's effectiveness.

For Question 1, 33 of 41 students participated in both rounds of answering. In the first round, students responded in an open-ended format. In the second round, the teacher used the CCR function to display all the answers recorded from students in the first round. Students were then asked to choose the most appropriate answer. Students' open-ended responses were categorized into five levels, as shown in Table 2.

Table 2. Coding of the open-Ended Response Rating Scale

Level	Assessment
1	Off-topic.
2	Wrong answer.
3	Correct answer but wrong explanation.
4	Correct answer but does not mention the conversion between kinetic energy and potential energy.
5	Correct answer with explanation of the conversion between kinetic energy and potential energy.

Based on the coding scheme presented in Table 2, the responses of the 33 students who participated in both rounds were classified into five assessment levels. The number of students at each level was calculated separately for both rounds, after students had received additional prompts from the teacher and had the opportunity to exchange and discuss their ideas with one another. Figure **3** presents the distribution of students across Levels 1–5 in the two rounds.

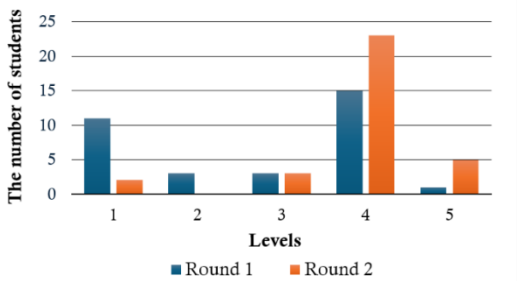


Figure 3. Results of Open-Ended Responses

Notably, only two students remained at Level 1 in the second round. This may be due to a lack of understanding regarding the CCR's voting function for open-ended responses or a lack of engagement in the response process, leading them to select answers randomly. These responses were off-topic and thus could not be evaluated as correct or incorrect. Meanwhile, the proportion of students providing high-level responses (levels 4 and 5) increased markedly, rising from 48.5% to 84.8% of the 33 participating students. This improvement suggests that students refined their responses in the second round by reviewing and selecting appropriate answers from their peers. Importantly, students were unaware of the authorship of the responses, as the CCR interface displayed only the content. Consequently, most students demonstrated objective judgment in evaluating peer responses and successfully identified answers that aligned with the given prompt.

These findings support the effectiveness of essay-based questioning in team-based learning, as introduced by Crouch et al. (2007), in enhancing students' comprehension of physical phenomena. The CCR platform proved to be a valuable tool in facilitating this activity, as its features aligned well with the nature of the questions and the pedagogical requirements of the team-based learning approach. For multiple-choice Questions 2 and 3, the initial correct response rate was low. However, it gradually increased through multiple discussion rounds, particularly when the teacher provided guidance and prompts.

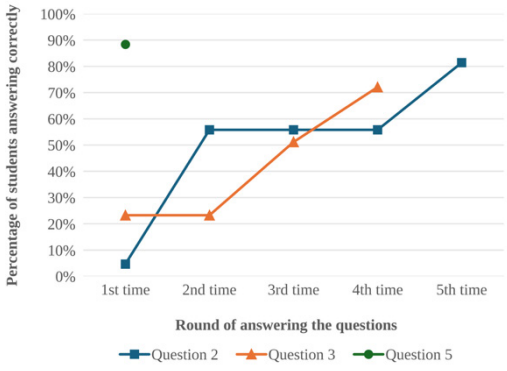


Figure 4. The Ratio of Students Answering Each Time Correctly

Figure 4 presents the aggregated percentage of correct answers across multiple attempts for all three questions used in the lesson. Question 2, which addresses the conditions for the conservation of mechanical energy, required five rounds of responses before reaching an accuracy rate above 80%. Although there was a significant improvement after the first discussion—rising from 4.65% to 55.81%—subsequent increases were marginal. Only in the final round of teacher-led analysis, when individual scenarios were examined in greater depth, did the correct response rate exceed the 70% threshold. Question 3, which involves applying the law of conservation of mechanical energy, required four rounds of responses before the proportion of correct answers exceeded the 70% threshold (about 72%). While there was a steady increase in accuracy after each discussion, surpassing the threshold required additional teacher support. More explicit guidance on how to apply the law effectively was necessary in the final attempt. Question 5, a quantitative problem, yielded remarkable results from the outset, with an initial accuracy rate of 88.37%. This suggests that students could leverage knowledge gained from previous questions to solve the problem without requiring multiple discussion rounds, as seen with questions 2 and 3.

Based on the increase in the percentage of correct responses from the initial to the final attempt, the results indicate that conceptual improvement was not automatic but emerged through iterative cycles of peer explanation and adaptive teacher facilitation. When students' accuracy rate stood below the 70% threshold, CCR feedback made cognitive bottlenecks visible in real time, allowing the teacher to refine prompts—from broad exploratory cues to more targeted scaffolds—to help students clarify misconceptions. This pattern is consistent with formative assessment principles (Parmigiani et al., 2024) and reinforces findings reported by Chan and Chang (2018), who noted that CCR-supported peer discussion enhances conceptual processing. Taken together, these findings show that conceptual gains in this setting were driven by responsive instructional adjustment aligned with students' actual reasoning, rather than by PI use alone.

The findings from this classroom-based case suggest several considerations for implementing technology-supported PI in physics education beyond the Vietnamese context. First, pre-lesson preparation appears to be important for creating sufficient classroom time for conceptual interaction and for enabling students to participate more confidently in peer discussion, consistent with findings from flipped-classroom research (Ngo & Md Yunus, 2021). Second, the effectiveness of a technology-supported peer-learning cycle depends not only on the availability and features of the digital platform but also on timely and targeted teacher facilitation. In this study, teacher responses to students' emerging difficulties were necessary to maintain lesson progress and

support conceptual refinement. Third, conceptual questions need to be carefully designed and matched to students' proficiency level and available instruction time. Questions that are too demanding may require additional discussion and teacher support, whereas well-calibrated questions can help sustain productive interaction. These observations suggest that the pedagogical value of digital response systems lies less in the technology itself than in how teachers use it to monitor student thinking, organize peer interaction, and adapt instruction in real time (Cabero-Almenara et al., 2021).

The Vietnamese case is relevant because it illustrates how a cloud-based response platform can be integrated into a competency-oriented physics curriculum while retaining the core principles of PI. Although the study was conducted in a single Vietnamese classroom, the implementation provides a concrete example of how digital response systems can connect conceptual learning with communication and collaborative reasoning in competency-oriented physics instruction. Similar design principles may be relevant in other educational settings where teachers seek to combine active learning with digital formative assessment, although adaptations may be necessary to account for differences in curriculum, classroom norms, student digital literacy, and available technological infrastructure. Research on PI and digital response tools has been conducted predominantly outside Southeast Asia, where the few available studies have examined PI with other response tools or in flipped classroom formats (Wuttiprom et al., 2017; Aslamiyah & Tyas, 2025). Access to educational technology in the region remains uneven, and evidence of its impact on teaching and learning remains limited (Global Education Monitoring Report Team & SEAMEO, 2023). In settings where schools are moving towards competency-based curricula but have limited access to dedicated response hardware, a free, cloud-based platform that runs on ordinary internet-connected devices offers a feasible route to implementing PI without clickers. The Vietnamese case therefore adds classroom-level evidence from an under-represented region and indicates which elements (i.e., pre-class preparation, threshold-based decisions on when to open peer discussion, and real-time teacher facilitation informed by platform data) practitioners in comparable Southeast Asian contexts may choose to adapt.

Several limitations should be considered when interpreting these findings. The small sample size (41 students) and the absence of a randomized control group restrict the generalizability of the results. In addition, the low homework completion rate reduced the consistency of students' preparation, and some conceptual questions did not fully align with students' proficiency level or the available lesson time. Because the intervention was implemented just once (over two consecutive class periods), students may also have had insufficient time to become fully accustomed to the pace and routines of PI. The study yields evidence from a specific classroom implementation and therefore does not constitute a basis for establishing the effectiveness of PI–CCR across contexts.

The study also relied partly on self-assessment data, which may be influenced by students' subjective perceptions (Nieminen & Tuohilampi, 2020). Differences in digital literacy and written communication skills may likewise have affected the quality of students' interactions through CCR. These concerns are consistent with previous research highlighting the importance of learner engagement, teacher competence, and contextual conditions in technology-supported collaborative learning (Zaid et al., 2018; Cabero-Almenara et al., 2021; Mohammadi et al., 2022; Wicaksono et al., 2022). Future research should therefore examine the PI–CCR approach across larger and more diverse samples, longer instructional sequences, and different educational settings. Such research would help determine which implementation features are context-dependent and which may represent more broadly transferable principles for technology-supported active learning in physics and other science subjects.

CONCLUSION

This study's findings show that integrating PI with the CCR platform enhanced students' conceptual understanding and communication competence. Through structured peer discussions supported by CCR, students could articulate reasoning, identify misconceptions, and refine their understanding of key physics concepts. This integration aligns with the competency-based orientation of the Vietnamese General Education Curriculum and shows that combining digital response systems with interactive methodologies can create more engaging, student-centered physics lessons.

Beyond the Vietnamese setting, the study offers a concrete example of how a free cloud-based response platform can be embedded in a competency-oriented physics curriculum while retaining the core principles of PI, and it adds

classroom-level evidence from Southeast Asia. Given the single-class design and the short intervention, these findings should be regarded as indicative rather than conclusive. Future studies with larger and more diverse samples, comparison groups, and longer instructional sequences in physics and other science subjects are needed to establish which features of the PI–CCR approach are transferable across contexts.

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